

SUSTAINABILITY AND INNOVATION: AN ANALYSIS FROM A SYSTEM  
PERSPECTIVE IN AGRICULTURE

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By

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## ABSTRACT

This study was carried out to examine how innovation can support sustainability and why these two concepts are important for agriculture. To do this, it was necessary to explore the meaning of sustainability and innovation for sustainability, the barriers and opportunities in building a local innovation system by identifying learning interactions, and the role of higher education institutions in achieving sustainability. Since there has been no empirical study of innovation and sustainability in agriculture from a bottom-up perspective, a qualitative case study with multi-methods approach was conducted. The field study took place in Yucatán, México, in the Conkal community over a period of three months in 2013. This research was comprised of in-depth interviews with stakeholders involved in habanero chile farming to identify their perceptions, challenges, and the nature of their willingness and practice of innovation and sustainability. Both Strengths, Weaknesses, Opportunities, Threats (SWOT) and document analysis were used to complement the interview evidence. The results highlight the interpretations of sustainability principles (economic, ecological, and social) and the flow of knowledge and learning interactions that are occurring in the habanero chile product system. To increase innovation capacity, the integration of multiple local players is important to create local innovation systems that can also achieve sustainability principles.

The study suggests that learning interactions and knowledge networks at the local level can be used to develop and disseminate technological and non-technological innovation for social, economic, and ecological improvement in farming. Such improvements should be supported by higher education institutions by generating, transferring, and applying ideas, resources, and programs to local communities. Higher education institutions should work towards the integration of various types of knowledge and increase engagement with local farming needs. However, the willingness and trust of individuals as well as the lack of leveraging opportunities to innovate for sustainability were perceived as barriers.

The key contribution of this study is to highlight and promote how innovation systems at small scales can support sustainability that may lead to a quintuple helix model (one that integrates the following five components: university, government, industry, civil society, and natural environment). The most important aspect of this study is the suggestion that the integration of social, ecological, and economic goals in innovation systems can help shape an approach that can reorganize innovation for sustainability. Such suggestions are described in the results and discussion sections.

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## DEDICATION PAGE

With infinite love to my family:

Rosalinda, my mother and best friend.

Christopher and Maximiliano, my sons, for being my inspiration!

Ofemelia and Gilberto, my sister and brother, for always being there for me.

Gilberto, a good storyteller and father.

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## TABLE OF CONTENTS

PERMISSION TO USE .....	i
ABSTRACT.....	ii
ACKNOWLEDGEMENTS .....	iv
DEDICATION PAGE.....	v
TABLE OF CONTENTS .....	vi
LIST OF TABLES .....	ix
LIST OF FIGURES.....	x
CHAPTER ONE .....	1
INTRODUCTION .....	1
1.1 Statement of Purpose and Objectives .....	5
1.2 Study Area and Approach .....	6
1.3 Contribution to Knowledge .....	6
1.4 Thesis Organization.....	7
CHAPTER TWO .....	8
LITERATURE REVIEW .....	8
2.1 Introduction .....	8
2.2 Knowledge and Learning .....	9
2.3 Learning Theory .....	13
2.3.1 Learning for Sustainability and Innovation .....	15
2.4 Innovation .....	16
2.5 Sustainability .....	17
2.6 Sustainable Innovation versus Innovation for Sustainability .....	20
2.7 Sustainability, Innovation, and Agriculture: A System Perspective .....	22
2.8 Sustainability System .....	23
2.9 Innovation Systems .....	25
2.9.1 Triple Helix .....	26
2.9.2 Quintuple Helix .....	27
2.10 Sustainability and Innovation in Higher Education Institutions .....	29
2.11 Contextual Setting: Agriculture .....	31
2.11.1 Agricultural Innovation System.....	31
2.11.2 Agriculture and Sustainability .....	33
CHAPTER THREE.....	36

RESEARCH METHODOLOGY .....	36
3.1 Description of Research Methodology .....	36
3.2 Study Area and Rationale .....	39
3.3 Data Collection.....	45
3.3.1 Document Analysis .....	45
3.3.2 Stakeholder Analysis .....	46
3.3.3 Focus Group .....	49
3.3.4 Strengths, Weaknesses, Opportunities, Threats (SWOT) Analysis.....	50
3.4 Data Analysis .....	52
3.5 Reliability of the Research .....	57
3.6 Significance and Limitations .....	58
CHAPTER FOUR.....	61
RESEARCH FINDINGS .....	61
4.1 Understanding Sustainability and Innovation for Sustainability .....	61
4.1.1 Sustainability Perspectives .....	62
4.1.1.1 Social Sustainability .....	67
4.1.1.2 Environmental Sustainability.....	69
4.1.1.3 Economic Sustainability .....	70
4.1.2 Innovation for Sustainability .....	74
4.2 Local Innovation System .....	79
4.3 Learning Interactions.....	85
4.3.1 The Creation of Inter-multidisciplinary Groups.....	88
4.3.2 Knowledge and Learning Networks .....	91
4.3.3 The Integration of Scientific and Traditional Knowledge.....	94
4.4 Barriers and Opportunities in Building Local Innovation Systems.....	99
4.5 The New Role of Higher Education Institutions.....	106
4.5.1 Knowledge Generation .....	107
4.5.2 Knowledge Transfer .....	108
CHAPTER FIVE.....	114
DISCUSSION AND INTERPRETATIONS OF FINDINGS .....	114
5.1 Sustainability and Innovation at Local Farming Spaces .....	115
5.2 Innovation for Sustainability .....	120



5.3 Opportunities and Challenges in Building Local Innovation Systems Towards Sustainability .....	129
5.4 The Function of Sustainability in Agricultural Innovation Systems: An alternative.....	139
5.4.1 Implications .....	142
5.5 The Perspective of Quintuple Helix in Local Spaces.....	148
CHAPTER SIX .....	151
CONCLUSIONS.....	151
6.1 Limitations and Further Research.....	157
REFERENCES.....	158
APPENDICES .....	170
Appendix A: HEI Consent Form (English) .....	170
Appendix B: HEI Consent Form (Spanish) .....	173
Appendix C: In-depth Interview Guide .....	176
Appendix D: Focus Group Guide.....	178
Appendix E: SWOT Analysis Guide .....	180

## LIST OF TABLES

<u>Table</u>	<u>page</u>
2-1. Types of Knowledge.....	10
2-2. Modes of Knowledge Creation and Translation.....	11
3-1. Documents.....	46
3-2. Participant Pool.....	50
3-3. Research Components.....	56
4-1. The Beliefs and Actions of Sustainability.....	64
4-2. Summary of Sustainability Perspective .....	73
4-3. The Understanding of Innovation for Sustainability.....	78
4-4. Three Elements of a Local Innovation System .....	83
4-5. The Benefits of Learning Interactions .....	98
4-6. The Identification of Barriers and Opportunities for Sustainability.....	105
4-7. Three Roles of HEIs in HEI in Agricultural Innovation Systems .....	112

## LIST OF FIGURES

<u>Figure</u>	<u>page</u>
2-1. Strong sustainability and its dimensions .....	19
2-2. Co-evolution from triple Helix to quintuple Helix .....	28
5-1. The integration of categories and principles of sustainability .....	116
5-2. The function of sustainability in innovation systems .....	141
5-3. Integration of a quintuple helix at a small scale (a cluster).....	149

## CHAPTER ONE INTRODUCTION

Sustainability is important to environmental preservation (Millennium Development Goals, 2012). Pearce, et al. (1989) describes sustainability as the non-decrease of natural capital. This description notes that natural capital supports all economic systems while sustaining future generations. Natural capital consists of all natural resources that are needed to produce goods and services. Agriculture is an important part of these natural systems and can complicate our perspective on sustainability, as production from this sector tends to increase as it approaches monoculture and as a result causes declining diversity (one element of ecosystem sustainability) (Gliessman & Rosemeyer, 2010). However, some recommendations concerning the creation of a new sustainability framework to complement the environmental dimension have been proposed that might accommodate agricultural development and growth (Evans & Steven, 2012). The members of the Rio+20 conference in June 2012 concluded that there is a need to better integrate and balance the three dimensions of sustainability (economic, ecological, and social). For instance, this integration can improve farming production, manage natural resources, and hold employment in agriculture, through obtaining better income, and protecting the culture and language of small farmers. In this sense, Evans and Steven (2012) recommend a new sustainability approach to join ecological, social, and economic dimensions toward an integrated approach of sustainability by Millennium Development Goals 2015. This new sustainability approach considers the creation of local group of people that share similar attitudes and interests and strong regional regimes, where local, regional, and national stakeholders and governments can co-produce and apply sustainability goals.

The lack of clarity on what sustainability means for agriculture or how it should be integrated represents an opportunity for new ways of doing, knowing, and learning. Thus, aspects of innovation can support sustainability goals (Leach et al., 2012). Innovation can contribute to sustainability not only through the design of new products or methods for improving production and service systems, but also in the creation of new policies, programs, and creative forms of collaboration among multiple actors (International Council for Science, ICSU, 2005). Hence, innovation should not be seen only as a vehicle for

economic growth with a focus on technology, but as one of many contributors that can benefit society and the environment, particularly (in this case) in support of sustainability. However, there is no clear definition of innovation for sustainability and there is little research that suggests or contributes to a conceptual framework that integrates innovation and sustainability. Hence, there is a need to study what innovation for sustainability means and how innovation can support sustainability (Leach et al., 2012). It is hoped that a new approach to sustainability through innovation will be developed as a result of this study, which is an empirical examination of how innovation can enhance sustainability.

A new approach to study innovation for sustainability should be based on how to reconnect (or connect for the first time) top-down decision makers and bottom-up actors to achieve sustainability goals. For instance, a connection between large-scale farmers and traditional (mainly indigenous) farmers might improve crop management and water conservation by exploring methods that could scale up traditional practices to achieve both goals in larger holdings (Norberg-Hodge et al., 2002). Boosting the presence and use of knowledge networks and learning interactions among multiple players in local communities is valuable. ICSU (2005) emphasizes formal and informal companies, grassroots initiatives, and inventions working toward sustainability. Thus, building local learning communities can help such farmers face social, ecological, and economic problems in a unified manner. Nevertheless, the necessary interaction among different players and disciplines in a dynamic local environment that is committed to sustainability is difficult to generate and maintain (ICSU, 2005). Leach et al. (2012) describe the importance of local and regional government interaction with industries, farmers, civil society, and other players to ensure the success of sustainability goals. This interaction would identify the benefits of learning and sharing inside social groups. Local learning and knowledge networks should be seen as the basis for the improvement of production and related systems in service of sustainability. However, sustainability-based innovation, which utilizes local learning interactions and knowledge networks, has not been comprehensively examined.

Farming, particularly small scale and traditional agriculture, is essential to reducing inequality. Improving social cohesion and learning interactions in small agrarian

communities would address problems and inequalities that farmers face today, such as healthy food, productivity gaps, and poverty (Stanton, 2012). These problems also include how individuals and corporations leverage knowledge, as well as the socio-economic conditions of each of the parties involved (Spielman & Birner, 2008). The World Bank report on agriculture for development (2008) highlights the significance of agriculture based-economies and small-scale agriculture for reducing poverty, particularly in developing countries. However, critical issues need to be addressed, these include: a) ensure access to healthy food, b) strengthen institutions and knowledge networks, and c) build a well-coordinated and formal relationship between top-down and bottom-up local agricultural players towards sustainability. This provides an opportunity for farmers of all types to improve the productivity, profitability, and sustainability of their farming system through local innovation systems, which are generally multifaceted and include interactions between different individuals and institutions (Spielman & Birner, 2008). Learning interactions and knowledge sharing networks provide an opportunity to leverage already successful practices in order to benefit local innovation systems to achieve sustainability goals in agriculture.

Research centers, universities, industries, farmers, and public institutions, as part of the local innovation systems, should interact for the expansion and consolidation of agro-systems. Universities should be leaders in promoting sustainability goals, innovation, and knowledge. Beneficial and innovative breakthroughs for society that are made inside Higher Education Institutions (HEIs) by researchers and students should consider social, economic, and ecological sustainability. Nevertheless, many studies about HEIs are focused on their role of contributing to regional development and innovation processes without considering sustainability. HEIs may support sustainability by facilitating different ways of knowing and thinking, framing cultural values, as well as providing diverse mechanisms to develop and transmit technological and non-technological innovation (ICSU, 2005). For example, HEI research can contribute to agriculture development through the rational use of water, food security, and soil quality to build better food systems (Leach et al., 2012). HEIs should also be working with society, other researchers, farmers, alumni, industrials, and authorities to create local agricultural communities that preserve sustainable practices

and products towards the goal of developing new ideas and supporting continuous social and ecological improvements (Gliessman & Rosemeyer, 2010). For instance, HEIs can identify community problems or opportunities related to both technological and non-technological projects that might improve quality of life. This new structure involves institutional changes and adaptations to create the necessary conditions for building local communities of knowledge that work on sustainability (Vollenbroek, 2002). Yet, barriers exist that prevent cohesion between HEIs and local players, particularly in the realm of innovation for sustainability (Carayannis & Campbell, 2012). Thus, a holistic approach to understanding the role of HEIs as local innovation drivers in across-scale in the realm of sustainability is needed.

This research provides a conceptual approach to how innovation can enhance sustainability. This will be achieved through the analysis of multiple stakeholders' views, particularly through a bottom-up approach to agriculture (farmer-focused). Leach et al. (2012) indicated that it is important to empower grassroots players who can participate in comprehensive and multi-level innovation for sustainability. An empirical analysis will summarize how players at multiple levels describe both sustainability and innovation for sustainability. The aim is to analyze how learning may support achieving sustainability goals through innovation. Thus, identifying barriers that may be limiting the emergence of local innovation systems and uncovering new approaches to knowledge mobilization and learning are necessary. For instance, two types of innovation systems will be analyzed and discussed as regards the engagement of local players in learning and knowledge networks. This analysis will help us better understand how innovation systems can contribute to sustainability. This study will also help decision makers identify and take advantage of opportunities related to learning, innovating, and stakeholder interaction. Thus, a conceptual and analytical framework will be proposed to build local innovation systems for sustainability. Another challenge for innovation contributing to sustainability goals is examining the creation of knowledge and the role of HEIs (Vollenbroek, 2002). Highlighting the importance of research and education will allow HEIs to identify the roles, structures, visions, and functions to integrate scientists and engineers with other local

players and civil society, in building technological and non-technological innovations that support sustainability in agriculture.

### **1.1 Statement of Purpose and Objectives**

The purpose of this dissertation is to examine the contribution of innovation to sustainability in agricultural practice. I focus on the contribution that learning interactions and innovation systems may play for local players who generate and transfer knowledge for human wellbeing and progress. The idea is to explore and analyze modes of innovation that may contribute to sustainability in agriculture, which can be applied and used in other sectors and regions. This is achieved by examining people's perceptions and actions and delving into sustainability and innovation policies. The further hope is that this research will provide insight regarding the significant role that local innovative initiatives play in achieving sustainability, as well as introspection on building local learning communities toward sustainability in order to connect local players with regional, national, and global sustainability activities. This thesis regards how local knowledge, technology, and experiences might transform the current local innovation systems to impact sustainability. I focus on the agricultural sector because of its need to be adaptive and sustainable under uncertain conditions, where the farmer is the key stakeholder, but a stakeholder who must be engaged in a network of innovation for sustainability (Norberg-Hodge et al., 2002). Three thesis research objectives were proposed to investigate how innovation can contribute to sustainability in agriculture:

- Analyze the ways in which local players understand sustainability and innovation for sustainability.
- Identify the opportunities and barriers in building local innovation systems through the exploration of how those players are learning to learn, interact, generate, and transfer knowledge.
- Illustrate what the role of higher education institutions is as builders of innovation for sustainability in agriculture.



## **1.2 Study Area and Approach**

The analysis was conducted on empirical evidence collected from multiple local players placed in the north of Yucatán, including farmers, executives, alumni, and researchers who were involved in a farming product system (habanero chile). This product was selected because of the active engagement of multiple players in projects related to habanero chile production and its revitalization for international markets. Few studies have analyzed a product system such as habanero chile, as a flow of knowledge and accumulated innovation among local multiple players (top-down and bottom-up) within a defined region toward sustainability. In this sense, I had the opportunity to illustrate how knowledge translation for innovation and sustainability is occurring in this region and what opportunities exist to rebuild local innovation systems. This study might be the basis for other studies and be applied to other systems, local communities, and regions outside of Yucatán where diverse players can interact and innovate for sustainability.

## **1.3 Contribution to Knowledge**

Sustainability has been broadly defined and applied for various purposes; innovation for sustainability has begun to emerge in different settings and sectors. This research introduces new perspectives and approaches regarding sustainability and innovation for sustainability in agriculture. The contribution of innovation to sustainability implies the presence of learning interactions, where local people generate and share new knowledge and thinking. The focus was to display how local players interact for learning and innovating in local settings. As this dissertation demonstrates, there are benefits associated with learning interactions, including the creation of knowledge networks and the integration of scientific and traditional knowledge. As well, this research is centered on examining local innovation systems towards sustainability. Since sustainability is little considered in innovation systems, the identification of sustainability as a new function represents an opportunity for future research and consideration. The quintuple helix model of innovation stresses a new possibility for knowledge generation, innovation, and sustainability highlighting the relation among university, industry, government, civil society, and

environment at regional and local spaces (Carayannis & Campbell, 2012). This study represents an opportunity and challenge for policy makers to address new innovation policies directed to sustainability, as well as for academic communities to encourage new thinking and knowing regarding innovation for sustainability.

#### **1.4 Thesis Organization**

The dissertation is structured in six chapters. Chapter two summarizes the related literature for this topic. I begin by explaining the basic understanding of knowledge transfer, learning, institutions, sustainability, and innovation. Then, I explain what a system is and an analysis of sustainability and innovation from a system perspective. The intention is to illustrate two models of innovation systems: triple and quintuple helix. These two models of innovation help clarify knowledge spaces and learning interactions among diverse actors. I present the quintuple helix model as a system that truly contributes to sustainability. I also examine studies regarding sustainability and innovation that take place in HEIs. It is then necessary to describe the context for knowledge and learning interactions across communities and scale, particularly the agricultural context. Chapter three introduces the methodology. I describe the research components, study area, rationale, and data analysis. In chapter four I present the qualitative results collected from interviews, SWOT, and document analysis. This chapter is divided in two main sections: a) understanding sustainability and innovation for sustainability, and b) local innovation systems. The first section illustrates the sustainability perspectives and beliefs and actions of stakeholders. Then, sustainability is analyzed according to its three principles: social, ecological, and economic. Innovation for sustainability is defined by stakeholders' interpretations and is presented as general overview. The second section discusses a local innovation system through learning interactions and knowledge networks in the product system. The analysis of barriers and opportunities for building local innovation systems is offered. Furthermore, an analysis of the role of HEIs as an important player and contributor of innovation and sustainability is highlighted. Chapter five is the discussion and interpretation of results regarding the purpose and objectives of the research. Chapter six provides my research conclusions that emphasize the importance and ways of innovation contributing to sustainability. The limitations and suggestions for future research are also included.

## CHAPTER TWO LITERATURE REVIEW

### 2.1 Introduction

Innovation systems have emerged to generate and mobilize knowledge, skills, and technology among institutions and society. When considering the impact that knowledge mobilization for innovation can have on a community, it is essential to consider its economic, social, and ecological impact. This impact includes dynamic learning and adaptation that can be achieved across the three sustainability dimensions: the ability to preserve the environment, maintaining economic standards while ensuring a high quality of life, and the identification of social needs for prosperity (UN, 2002; Robinson, 2008). This research will investigate learning interactions among key players in order to explore how innovation can contribute to the social, ecological, and economic welfare of farming communities. Innovations can come from within or outside the farming community; no matter their origin mobilizing such innovations requires interaction among stakeholders so beneficial innovations can spread. For instance, the level of involvement of relevant individual stakeholders might help us identify barriers to innovation spread or what relationships facilitate innovation spread. Learning is crucial and is required for both sustainability and innovation. Learning by doing and learning by interacting can generate new ideas and solve problems. In a learning economy, institutions must increase their skills and capacity to learn in order to better respond to the demands of sustainability and market opportunities (Lundvall, 1996). Innovation and sustainability demand a change in practice and a willingness to experiment. Communication and interaction, combined with knowledge mobilization allows innovation to benefit sustainability. This study examines how innovation can contribute to sustainability in agriculture through understanding innovation for sustainability, learning experiences, and appropriate knowledge structures for the transmission and adoption of innovation. This requires addressing the interconnectedness of the three dimensions of sustainability while analyzing local farming spaces from multiple perspectives. At the same time, innovation for sustainability has to highlight local learning interactions in the context of creating, sharing, and disseminating

knowledge. In order to understand the stakeholder interactions within this specific location and product system, an examination of the terms that were used for this research is appropriate.

This literature review is organized thematically, providing an overview of the themes related to the research. The goal is to analyze, interpret, and compare multiple points of view, actions, and experiences in this particular farming system to clarify elements concerning innovation, sustainability, knowledge, and learning interactions. I start with the chapter describing the basic understanding of knowledge, learning, innovation, and sustainability as the broad themes of this research. I present theories and studies conducted in the context of these themes. I describe several approaches to innovation and sustainability in agriculture and in HEIs and give examples of how diverse authors have approached innovation for sustainability. In this research, knowledge and technology transfer should include new ways of generating innovation in the realm of sustainability. For this reason, an important element is the comprehension of how knowledge is being created and shared, and by whom. Learning as a key component in innovation and sustainability and is analyzed as well. How local players learn, share, and innovate for sustainability is part of this. Then, an examination of what a system is, as a basis for studying innovation, sustainability, and agricultural systems is described. I also examine the new role of HEIs along with other local players promoting knowledge and learning networks in favor of sustainability. This chapter concludes with the philosophical approach that marks the nature of knowledge and the philosophical worldview that guides this research.

## **2.2 Knowledge and Learning**

Knowledge is related to beliefs, values, perceptions, thoughts, and interactions among individuals (Blindenbacher & Nashat, 2010). For this reason, transferring knowledge in innovation and sustainability systems in the face of socio-cultural barriers, lack of trust, or lack of information is complex (Fabricius et al., 2005). Knowledge depends on how individuals and organizations communicate, collaborate, and learn (Lundvall, 1992). Knowledge and learning by individuals and by social collectives requires social

transformation and critical reflection for sustainability (Diduck et al., 2012). The following types of knowledge: know-why, know-what, know-how, and know-who are presented in table 2-1.

Table 2-1  
*Types of Knowledge*

Know-why	This knowledge relates to phenomena, principles, and laws of activity in nature, and in the individual intellect.	Social
Know-what	Knowledge based on fact. People can obtain learning and knowledge from different sources: books, CDs, data bases, and other people.	Individual
Know-how	This knowledge has a relation to processes, procedures, and skills.	Individual
Know-who	This knowledge involves information and social relationships with expert groups.	Social

Source: (Foray, 2004; Lundvall, 1996).

Know-why consists of knowledge that can be codified, transmitted, and can evolve to study new empirical phenomena through collaboration. Know-what is formal knowledge held by professionals and is related to cognitive abilities. Know-how is non-conscious knowledge that allows an individual to understand and codify knowledge through learning. Know-who is collective knowledge (rules and routines) that allows individuals to share knowledge in a social group (Lundvall, 1996; Amin & Cohendet, 2004).

Knowledge translation is a broad term that refers to the creation of knowledge and its communication and application (Stratton, 2005). Knowledge translation is the multi-directional flow of information among several actors. An important distinction within knowledge translation is that of formal and informal knowledge (Fabricius et al., 2005). A set of universal rules for a particular use is known as formal knowledge; while informal knowledge is subject to local rules of authenticity. Understanding how knowledge is created and learned both tacitly and explicitly is important (Nonaka, 1994). Tacit knowledge can be described as unconscious knowledge that we hold in our minds, it can be acquired by experience, but is difficult to express. In contrast, explicit knowledge can be shared in social processes, can be planned, and can be expressed through diverse mechanisms (Nonaka, 1994; Blindenbacher & Nashat, 2010). Chang and Chen (2004) state

that technological knowledge is difficult to share and transfer, because this knowledge is tacit and involves complex issues. However, Amin and Cohendet (2004) say that knowledge resulting from learning in communities can become codified by researchers, scientists, or students. The key lies in the ability and capacity of institutions, organizations, and people to absorb knowledge (Fabricius et al., 2005). Table 2-2 explains in detail how knowledge can be translated between and among people and groups and learned through modes of knowledge creation: socialization, externalization, internalization, and tacit-explicit knowledge combination (Nonaka, 1994). It is important to note that a knowledge source (tacit or explicit) can be translated to a knowledge receiver, resulting in either tacit or explicit knowledge as an outcome.

Table 2-2  
*Modes of Knowledge Creation and Translation*

Socialization	Creating tacit knowledge through observation, imitation, and practice from one individual to another. It is difficult to transfer critical thinking among people.	From tacit to tacit knowledge.	Formal knowledge in which people are trained scientifically.  It is informal knowledge when this is embedded in local traditions, memory, and customs.
Externalization	This mode involves tacit and explicit knowledge. The goal is that persons can share their personal beliefs and perceptions with other people, even positive or negative experiences. It is an interactive process of contributions.	From tacit to explicit knowledge.	Can be formal or informal knowledge. This depends on the type of meaning that is being applied to codify knowledge (manual, assessment procedure, or oral history).
Internalization	This mode is from explicit to tacit knowledge, by which each person should apply introspection concerning his own experiences and practices. Persons should also ask questions about the procedures, or what they do not know.	From explicit to tacit knowledge.	Undefined because people use the memory and cognition to internalize knowledge.
Combination	Involves creating explicit knowledge through social processes, and using combined mechanisms. People can share, exchange, and add knowledge toward the generation of new knowledge.	From explicit to explicit knowledge.	Knowledge can be formal or informal depending on the type of mechanisms (social networks, social media, clubs, incubators, training programs, or events).

Source: (Nonaka, 1994; Blindenbacher & Nashat, 2010; Fabricius et al., 2005)

Hoffmann, et al. (2007) conducted a study that shows the importance of knowledge, formal and informal research, and collaboration between scientists and farmers of two nations to produce innovation for agriculture with economic benefits. Disagreement appeared in relation to the roles of actors in formal and informal research, but an agreement between these actors led to an externalization of tacit knowledge. The results showed an innovation that farmers and scientists could produce over time. Cannarella and Piccioni (2011) identified and described traditional techniques practiced by rural farmers, which were externalized to scientists as a prerequisite to innovate and promote local development. Traditional knowledge is usually non-codified (tacit) because it is based on traditional beliefs, norms, and practices accumulated over centuries and transmitted orally to new generations (Correa, 2001). For instance, the use of biological materials for medicine and agriculture by local communities is part of local and traditional (tacit) knowledge. Traditional knowledge has existed for many generations and is immersed in local communities through their culture, customs, and laws (Mack et al., 2012). However, the term traditional knowledge does not mean that it only belongs to the past, but refers to the process through which knowledge is created or acquired (Snively, 2009). Meyer (2011) explains that traditional knowledge is developed through experience, where everything is interconnected by the values and beliefs of people.

Some authors have described traditional knowledge as that which is shaped by social values and traditional norms, particularly in a geographic area, where local knowledge is related to the traditional through political, economic, and cultural factors (Dei, 2000). Torri and Laplante (2009) explored how traditional knowledge can help local stakeholders innovate in a more active and intimate way to promote local health practices. One of the drawbacks they identified of such knowledge is that it is not properly protected by copyright laws. This has led to some researchers and corporations appropriating traditional knowledge (Correa, 2001). This has the unfortunate outcome of making the holders of such knowledge suspicious and perhaps less likely to share. For example, in some farming communities, the seed supply relies on the informal system of seed production, where many traditional farmers plant and use a variety of seeds for their agricultural system, but they are not used

to applying for, or procuring, patents for their seed production system. In fact, such farmers are quite unlikely to have the capacity or resources to take such action.

The Nagoya Protocol on Access to Genetic Resources was established in 2010 by the Convention on Biological Diversity. This is a legal framework to protect inventions based on the use of genetic resources (related with traditional knowledge, or not), and there is an agreement for fair and equitable benefit-sharing (World Intellectual Property Organization, WIPO, 2015). The way to protect knowledge depends on the potential, application, and ownership of the knowledge (Correa, 2001). However, an international law that protects other traditional forms of creativity and innovation as intellectual property is still incipient (WIPO, 2015). Thus, traditional and local knowledge should be protected by considering the extent to which it relies on a learning interaction with scientists and other social players, leading to the equity of diverse ethnic groups in protecting their individual and collective ideas. In this sense, scientists can learn from the holders of traditional knowledge, traditional practices can be preserved, and traditional and non-traditional knowledge can help conserve biodiversity. Scientists have recognized lately that indigenous knowledge may help generate knowledge and find solutions to needs and problems along with technological knowledge (Correa, 2001). However, Simpson (2004) says that the integration of traditional and scientific knowledge have failed because indigenous values differ from the western/colonial worldview.

### **2.3 Learning Theory**

Learning involves processes associated with developing new actions and practices in the face of uncertainty or need. In this way, learning should include doing, using, and interacting. Each of these types of learning is related to experimental activities, the interaction of different players with diverse skills and knowledge at different scales and spaces, and an increase in expertise (Lundvall, 1992; Amin & Cohendet, 2004; OECD, 2004). For instance, a farmer can shift from typical farming to hydroponics by observing other local farmers, determining production capacity, the potential for future demand, the benefits and problems in terms of cost and revenue, and individual and group relationships.



Thus, learning is a dynamic and social process that involves cognition, engagement, participation, and the development of new practices and perceptions.

In the context of sustainability and innovation there are three levels of learning: single loop, double loop, and triple loop. Single loop learning is making current practices better or correcting errors in current practice. Double loop learning implies not only correcting errors, but also altering values, perspectives, and goals. Triple loop learning refers to the design of social norms and rules through a reflective mechanism to promote change, social network participation, and system orientation (Armitage et al., 2008; van Mierlo et al., 2009). For example, a shift to a different crop technique requires a new farming system, new objectives, more interaction with and learning from other people, a change in attitude and values, and establishing new policies to implement and operate the new farming technique. Transformative learning involves a critical examination of individual experiences and a move to action (including traditional people), thereby developing a social transformation. This type of learning is a reflective process that allows adjustment to perception and engagement (Mezirow, 1995, Armitage et al., 2008). Transformative learning involves instrumental and communication outcomes. Instrumental outcomes include new technology solutions, task-oriented problem solving, as well scientific-technical and ecological knowledge. Communication outcomes include shared values and goals, social engagement and mobilization, as well individuals insights related to reinterpreting meanings related to actions (Mezirow, 1995, Armitage et al., 2008; Diduck et al., 2012).

Two other learning outcomes have been identified from empirical research: transformative and sustainability-oriented outcomes (Diduck et al., 2012). These learning outcomes distinguish the social and ecological implications for economic development and identify the complex integration of social, economic, and ecological systems. These authors also identified that critical reflection occurs during learning. Learning involves iterative reflection through dialogue, practical methods, and individual and social action experiences and ideas with other stakeholders (Armitage et al., 2008; Diduck et al., 2012). However, not all transformational processes for sustainability derive from societal learning; they can also

come from planning, policy analysis, and public involvement (Diduck et al., 2012). For instance, a person can participate in a community project, such as the local production of solar energy, which might cause them to be introspective and reflect on the project's origin, development, implementation, and relative success. As a result, transformative learning can occur due to a behavior and/or attitude shift towards such projects. Knowledge transfer and transformative learning help build innovative actions for sustainability through the exchange of new ideas, new insights, and novel input from local actors. Conversely, good planning, well-built policies, and public engagement should be part of innovation and sustainability.

### **2.3.1 Learning for Sustainability and Innovation**

Accurate interpretations and continuous learning are required to confront the challenge of environmental and scientific uncertainties. Learning processes can contribute to our understanding of complex social systems including perceptions, point of views, and knowledge of diverse local players (Stagl, 2007). Learning can provide the solution to a particular problem through the exchange of ideas, multiple perspectives, shared attributes, and taking action. The resulting transformative learning can then contribute to innovation and sustainability outcomes related to both social groups and individuals. Some authors have used transformative learning to explain social collectives related to natural resources and environmental management (Diduck et al., 2012). In this way, sharing social values and meanings can occur through social interaction and open dialogue. However, a participatory action practice for learning might face certain challenges, such as: a) establishing the role of every person in the generation of knowledge; and b) determining and setting the proper relationship between civil society (considering local and traditional people) and government authority in learning interaction and decision making process. Thus, learning for sustainability and innovation is not a simple practice because it must happen in a complex and dynamic setting (Stagl, 2007). Milbrath (1989) states that a society that is learning for sustainability should overcome legal, social, and financial barriers to share and use available information, disseminate and use knowledge in better ways, think holistically in long-term and large-scale frames, learn values from others and relate the values to the interpretation of facts, combine theory and practice, and encourage

and empower civil society to promote learning and participate in decision making process. In this sense, the interaction of different actors with diverse skills and knowledge at multiple scales and spaces can lead to dialogue and diversity. Social groups and individuals can build new interpretations based on reflections on their own beliefs, explore new ways of being and thinking, make better decisions, and take action based on their new insight, all with the goal of supporting sustainability (Mezirow, 2000; Sinclair et al., 2011).

## **2.4 Innovation**

Knowledge is a key component of innovation. For this reason, innovation is a factor that can contribute not only to the economy, but also to society and ecology. In fact, innovation has fueled prosperity for developed countries and transnational corporations for many years. Innovation can be the application of an idea using technology, with the expectation that it will have an economic benefit; as a result, the development of goods and services and their commercialization to any segment of the market is also known as innovation (Phillips, 2007). Innovation is also used in research and development processes to create technological innovation. However, innovation is not only technology, but also includes social development, including skilled human capital, the diffusion and application of new knowledge, and acknowledgement of ecological and social challenges (ICSU, 2005). In this study, innovation is the creation of knowledge with a focus on changing action to achieve sustainability in agriculture, from a multidisciplinary perspective. The creation and transmission of ideas, skills, and information are relevant in innovation systems and networks because they can nurture creativity, reinforce knowledge, and result in learning within an existing institutional framework (Carayannis & Ziemnowicz, 2007). There are two types of innovation: incremental and radical. Ashford and Hall (2011) explain that incremental innovation involves co-evolutionary change; radical innovation is a disarticulation of existing or dominant institutions in the development of technology. In other words incremental innovation refers to small improvements of products, services, or processes, while radical innovation is a disruption resulting in a new product or service. For example, the reduction of costs due to the use of recycled inputs in a company is an incremental innovation, while the development of hybrid cars is a radical innovation.

There is a new perspective on how innovation is carried out that involves more dynamic interventions between users and producers. Von Hippel and De Jong (2010) describe two models of innovation: producer-lineal innovation and user innovation. Producer-lineal innovation is a traditional innovation model by which industry, firms, or other institutions have a goal of commercial success. This model of innovation, which is regulated by policy makers, moves from research to the development and diffusion of new products and processes. In contrast, user-innovators generate new products in order to supply their own needs and are not available on the market. User innovation may be a company or an individual that benefits from using an innovation. These user-innovators transfer knowledge and experiences to others and send information in informal ways (face to face, social media, or in practice). This type of innovation has little economic benefit and is not always patented (Von Hippel & De Jong, 2010). Perhaps a preferable model is to use multiple sources of innovation, including human capital inside corporations, linkages to customers, competitors, and other social network (Freeman, 1991). However, user innovation has problems related to the lack of technical skills, a weak collaboration among key players, and a lack of regulations and policies. The user innovator model plays a unique role in grassroots initiatives, where members of a community or civil association can generate new ideas and practices that bring not only economic, but also social and ecological benefits.

## **2.5 Sustainability**

Pretty (2011) points out that social change, learning, and innovation processes are part of the concept of sustainability. Innovation for sustainability should be supported by institutions to create research and development projects that benefit local communities. Technological challenges that institutions face concerning sustainability need to be addressed and new initiatives must be generated (Clark, 2003). New initiatives should strengthen institutions, their capacity, and the actors who are participating in learning, adaptation, and innovation for sustainability (Mog, 2004). The concept of sustainability has been defined by diverse authors and organizations for diverse purposes and settings.

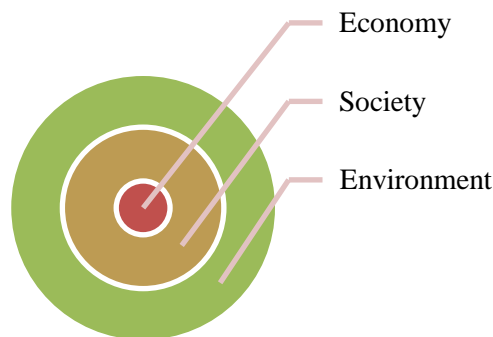
This concept of sustainability is best illustrated by natural ecosystems, which consist of nearly closed loops that change slowly. For example, in the food cycle of plants and animals, plants grow in the presence of sunlight, moisture, and nutrients and are then consumed by insects and herbivores which, in turn, are eaten by successively larger animals. The resulting natural waste products replenish the nutrients, which allow plants to grow and the cycle to begin again. If humans are to achieve truly sustainability, we will have to adopt patterns that reflect these natural processes. The role of engineers and scientists in sustainability can be illustrated by a closed-loop human ecosystem that mimics natural systems (WFEO, 2002, pag.13).

The Brundtland report introduced some normative principles including inter-generational, intra-generational equity, justice, participation, and gender equality. These principles have led to the establishment of rights and obligations for countries regarding social and ecological norms, and have helped policy makers elaborate better mechanisms and policies oriented to strengthen sustainability. According to Agyeman et al. (2003) sustainability is “the need to ensure a better quality of life for all, now and in the future, in a just and equitable manner, whilst living within the limits of supporting ecosystems.” (p.92). Frodeman (2011) defines sustainability science as an interdisciplinary area that analyzes the behavior and relationships between humans and nature and the responses generated from this interaction. Sustainability is a complex phenomenon occurring across scales and includes social, ecological, and economic dimensions (Avelino & Rotmans, 2011). Thus, sustainability for agriculture should consider economic, technological, ecological, and social analysis that emphasizes the importance of less intensive agriculture, new practices and learning, long term benefits, and the adaptation and resilience of agricultural communities. In general, sustainability in this research is synonymous with economic, welfare, biodiversity, and prosperity to ensure better living for all.

The interrelationship of the above aspects leads to the three sustainability dimensions (social, ecological, and economic); the interrelationship is based on the assumption that there should be limitations on the extraction of renewable and nonrenewable resources and how these are consumed, replaced, and allowed to replenish. There are two points of view about sustainability and the connectivity of its dimensions, i.e. weak and strong. Strong sustainability requires the protection of the environment as a precondition for economic development (Baker et al., 1997). This point of view has a direct relationship with the

precautionary principle, which refers to avoiding threats or irreversible damage to the environment. The replacement of natural capital by another similar capital is part of strong sustainability. For instance, the investment of renewable energy (solar) technology can balance the consumption of nonrenewable energy (oil). Weak sustainability refers to non-declining total natural capital (Dresner, 2008). This natural capital can be substituted and complemented by other capital, including human, and should be nominally conserved. For example, technological advances can replace both natural and human capital without the need for trees, nutrients soils, or individuals (Pearce et al., 1989).

Some authors disagree with strong sustainability; they believe there should be a degree of capital replacement as long as some minimal natural reserve is maintained. They argue that human-made capital will replace natural capital and its destruction is something unknown and inevitable (Beckerman, 1995; Dasgupta, 1993a). While others (economists, mostly) state that strong sustainability limits the replacement of natural capital and labour unless there is another resource that can replace them. They look for investment in future replacements; although they believe that nature cannot be substituted (Daly & Farley, 2004). These authors believe that the three dimensions of sustainability can be complemented rather than replaced. Strong sustainability is represented by three interrelated circles, as illustrated in figure 2-1.



*Figure 2-1. Strong sustainability and its dimensions*

This holistic perspective allows a better understanding of the interconnectivity of environment, society, and the economy. This represents a hierarchical interdependency where the environment is the dimension that provides resources to the economy and society. Thus, economy and society depend on the environment for production and

consumption of products and services (Dresner, 2008). The main idea is to preserve enough stock of wealth for a long and good life, which means that the path to progress is not bigger, but better.

## **2.6 Sustainable Innovation versus Innovation for Sustainability**

A balance between economic activities and sustainability, especially ecological sustainability, has been a challenge for many countries. Sustainable innovation or eco-innovation appeared as an imperative to limit the extraction of natural resources and protect the environment. However, it has been difficult to integrate economic and social approaches in this context (Rennings, 2000). Charter and Clark (2007) say that sustainable innovation is a process where environmental, social, and financial dimensions of sustainability are integrated through ideas, research and development, and commercialization. This can be applied to products, services, technologies, and to organizational models. In this sense, metrics, design, and eco-efficiency analysis are involved in sustainable innovation processes. To achieve eco-efficiency, consideration should be given to the modification of production and material composition, as well as the integration of technical and economic innovations (Dorf, 2001).

Innovation in support of sustainability is not very different from sustainable innovation. The main difference is that technology, actions, practices, and other aspects should be evaluated as a system; this means that all elements are interconnected and should be analyzed as a whole (Kemp, 2010). Some of the measures of sustainability include resource productivity, energy consumption, biodiversity, and greenhouse gas emissions. However, sustainability assessment should also consider an index of social, ecological, and economic well-being; these could include education, life expectancy, pollutant emissions, and investment in production processes (Stiglitz et al., 2010). Karakosta et al. (2010) argue that not only are production and intellectual capital relevant for innovation and sustainability, but also natural and social capital. In addition, innovation for sustainability should consider technological uncertainties and the complexity of the global civil commons. The civil commons involve human responsibilities regarding the interrelationship of all living organisms (animals, trees, and other humans), and the protection of nature for the well-

being of all people (Woodhouse, 2011). Potts (2010) explains that technology-based small companies can address unsustainable local problems and protect a civil commons related to water, energy, or waste, along with government, private, and public institutions. A natural advantage model was developed by Potts (2010) suggesting that small companies, civil society, and government can create a partnership that contributes to local communities using innovative technology, improving local identity, and being efficient in water, energy, and waste (Potts, 2010). Thus, the interaction of diverse players in the creation of innovative and appropriate technology for sustainability can help any sector develop products and services that contribute to sustainable and local development.

Grassroots initiatives for sustainability and innovation help us understand the role that civil society plays in innovation for sustainability (Seyfang & Smith, 2007; Carayannis & Campbell, 2010). Grassroots innovative niches are complex spaces where social and cultural rules are embedded (Seyfang & Smith, 2007). In fact, these niches also include traditional people. Some grassroots organizations include: cooperatives, voluntary associations, and social companies. These organizations have the goal of meeting social and environmental needs over economic. However, due to a lack of funding, the mechanisms to support grassroots initiatives, and some socio-cultural barriers make this initiative difficult to put into practice (Seyfang & Smith, 2007). Nevertheless, transformative innovations can help change the rules of actual systems (Moore & Westley, 2011). This transformation can be seen as social innovation where any idea, process, or methods can change routines, rules, and beliefs of a social system, as well as improve living conditions. Thus, for innovation to be transformative to sustainability a broad range of changes must occur: infrastructure, technology, social, and institutional (Kemp et al., 2005). Innovation that can contribute to sustainability is the focus of this research. In this sense, innovation should contribute to the improvement of the environment and biodiversity, healthy and productive social sectors, and sustained or improved quality of life for all. Innovation for sustainability should be based on the interrelation of multiple players, knowledge, needs, scales, and uncertainties. In this sense, there will never be a certain outcome, a right technology, or a simple formula to solve unsustainable problems because sustainability and innovation are systems in a constant co-evolution.



## **2.7 Sustainability, Innovation, and Agriculture: A System Perspective**

What is a system? It is the connection among different elements and objects interacting for a set outcome. Clayton and Radcliffe (1997) state that the world is a complex system where socio-economic and ecological elements are themselves complex sub-systems of a yet more complex system. This interconnection means that a simple change in one variable or element may alter another component of the system, causing unexpected outcomes or permanent transformations. The system concept is governed by cause-effect in accordance with a multi-level perspective. A change can provoke responses to multiple other systems, quite dramatically affecting the larger system. Spedding (1988) tells us that a system is a set of interacting elements for achieving a common purpose and is capable of responding to external factors including significant feedback. For instance, the telecommunication system has evolved and influenced human and business behavior. This system has changed the way people communicate, interact, produce, and learn. It is now easier to send a document via e-mail than to use conventional mail. Thus, a change element can cause a positive and negative effect, at the same time, in the system. In a rural agrarian community that might be interested in using innovation and innovation practices to pursue sustainability goals a system requires participants who have different expertise and a communication model that supports knowledge mobilization from one actor to another. For instance, a traditional Mayan farming technique can be communicated between the traditional farmer and other farming players to scale-up a technique for larger productions such as the use of water for irrigation purpose.

A system can be hard or soft (Spedding, 1988). A hard system includes the definition of goals and strategies, decision-making procedures, rules, laws, and norms. For instance, soil conservation and nutrient cycling are part of the regulation of a farming system. Soft systems include participatory action, common habits, routines, and traditions; decision making is complex due to the involvement of these factors along with human behavior, knowledge, beliefs, and values. In hard systems it is easier to apply a possible solution to a particular need because the structures are rigorous. Soft systems are more complex because

they entail human beliefs and actions, as well environmental uncertainties (Spedding, 1988). For instance, biotechnology, that implies patent protection for genetic material, is receiving an innovation regulation in terms of licensing for economic benefits, but no in terms of innovative sharing for social or ecological benefits because it is part of an institutional rule and structure. Both hard and soft systems can be more difficult to understand and apply in settings that include traditional and local knowledge. Traditional and local people have their own practices, beliefs, and norms. They can generate knowledge and innovation relevant to sustainable farming practices; as a result, the promotion and application of this type of knowledge should be protected by intellectual property law (Correa, 2001).

## **2.8 Sustainability System**

Food, water, housing, education, health, employment, justice, and technology are some elements of quality of life that are related to sustainability, and should be seen as part of a system that includes multiple stakeholders integrated both vertically and horizontally to supporting local economies. As well, it includes problems related to social, economic, and ecological issues, such as how to improve basic human needs, supporting clean and open ecological spaces, and how to manage equity and justice. Two of the nineteen principles of the Universal Declaration of Human Responsibilities state:

- “All people have a responsibility to protect the air, water, and soil of the earth for the sake of present inhabitants and future generations” (Article 7); and
- “... all people should promote sustainable development all over the world to assure dignity, freedom, security and justice for all people” (Article 9) (Redclift, 2006, p.77).

In this sense, the commitment of people, groups, and organizations towards the creation of a system of cooperation, cultural pride, and social cohesion will provide a foundation for sustainability as a system. However, different perceptions and interests can make the transition to sustainability hard to achieve (Moss & Grunkemeyer, 2010). Further, competition for resources and markets causes distrust and inefficiency in the sustainability relationships (Greg et al., 2010). Sharing common visions and values, as well as building civil commons through structures and functions can help to integrate sustainability system.

Different worldviews on sustainability have made it difficult to fully justify it being labeled or classified as a system. However, the three pillars of sustainability: society, ecology, and economy are interdependent and should be the foundation of any analysis of sustainability (Robinson, 2008). Visioning strategies for sustainability and how to balance these pillars will depend on the capacity of every person, institution, and social group to collaborate in support of knowing, adapting, and making more sustainable decisions. Only those individuals and social and political systems that are willing to meet and challenge specific interests, habits, and routines will engage with risks, uncertainties, changes, and adaptation (Blewitt and Tilbury, 2014). For example, an approach to support local communities addressing sustainability perspective has emerged from the Ohio State University Extension for Sustainable Development (Moss & Grunkemeyer, 2010). This approach consists of four visioning strategies:

- Inclusion. Create and engage an inclusionary committee to give guidance, and incorporate diverse people in the generation of the vision and the plan of the sustainability.
- Must be long term: Community planning should consider generational planning of at least four generations. Every 25 years a new social generation emerges; thus, participants must be encouraged to consider a vision that spans at least 100 years.
- Balance between the social, environmental, and economic dimensions is also necessary: Participants should think about balance and linkages among these dimensions, as the sustainability principle of interconnection. These dimensions should share the same goals, and make a significant contribution to a community.
- Must include multi-dimensional indicators: It is a guide to strengthen the interconnection of the economic, social and environmental dimensions. Also, these indicators support the goals of the community, and allow the participants check and receive feedback of all activities that impact and contribute the sustainability goals of the community. (Moss & Grunkemeyer, 2010).

This example shows how sustainability as a system may be possible with the inclusion of different elements, including the interconnection among structure, planning, local actors, and sustainability dimensions.

## 2.9 Innovation Systems

The concept of an innovation system was introduced by Lundvall in 1985. The term national innovation systems appeared in a book on innovation in Japan written by Chris Freeman in 1987. Freeman (2002) defines national innovation systems as “the network of institutions in the public and private sectors whose activities and interactions imitate, modify and diffuse new technologies” (p.193). Lundvall (1992) describes national innovation systems as a social and dynamic system that involves searching, exploring, and learning among organizations and institutions, such as research labs and universities. Such systems in the agriculture sector exist to develop new techniques and products and have well developed mobilization strategies that can be leveraged to communicate to users.

Coenen and Díaz (2010) describe three theoretical frameworks of innovation systems that are found in the literature on innovation, technological change, and sustainability. These frameworks are: sectoral systems of innovation (SSI), technological innovation systems (TIS), and socio-technical systems (STS). The authors point out that each framework addresses a different rationale for innovation and technological change. These authors suggest that a mixed framework is needed, which includes different ways of knowing and theoretical instruments to evaluate innovation for sustainability. Chang and Chen (2004) compared three systems of innovation: national, technological sector, and regional systems. The authors identify two methods for mapping innovation systems. These methods consist of organized links among networks, communities, and clusters (technological companies). Chang and Chen also present some of the most pressing challenges that innovation systems face with respect to policy makers and internal organizational changes.

Carlsson et al., (2002) present methodology and an analysis of different innovation systems. The authors focus on technological systems, as they consider this a whole system, dynamic and global. The authors conclude that relevant players were difficult to describe and the system’s performance was difficult to measure. To this end, Bergek et al., (2008) and Wieczorek and Hekkert (2012) propose a scheme of analysis that addresses a systematic approach to innovation including the characteristics, structures, and functions of

the development, diffusion, and use of a new technology. This scheme represents a practical analytic method to identify policy issues or system failures in technological innovation systems and can be used by researchers and policy makers for specific innovations. A local innovation system has not been defined clearly; however, social and learning dynamics are essential. In this way, diverse local players can generate knowledge and actions toward the improvement of their community. Thus, integrating local innovation systems in connection with education system, scientific institutions, civil society, and productive institutions would be essential for innovation systems studies.

### **2.9.1 Triple Helix**

The ‘traditional’ innovation system (recalling the short history of such systems) of university-industry-government has played an essential role in economic development and has evolved over time. These three components are combined in what is called the triple helix innovation model. This model started with government as the central axis embracing the other two players. This evolved into the triple Helix III model which offers a network of knowledge and innovation involving diverse actors at different scales (Etzkowitz & Leydesdorff, 2000). The authors describe Triple Helix III as follows:

*“An innovative environment consisting of university spin-off firms, trilateral initiatives for KBE, and strategic alliances among companies (large, small, and with different levels of technology), government laboratories, and academic research groups” p.112*

The interactions inside this network generate plans, strategies, and projects oriented mainly to the development of technology innovation. Innovation systems can be found at different levels crossing national borders, and creating complex systems of collaboration (Etzkowitz & Leydesdorff, 2000). As a result, the university-industry-government relationship implies new dynamics including institutional transformations, evolutionary mechanisms, and a new role for the university (Caniëls and van den Bosch, 2011). The university as a regional actor participates both innovation and learning dimensions (Caniëls and van den Bosch, 2011; Etzkowitz & Leydesdorff, 2000). A study was conducted by Casas et al., (2000) in The Bajío region in Mexico to identify the structure and dynamic of knowledge/innovation networks according to the triple helix model in different technological areas including

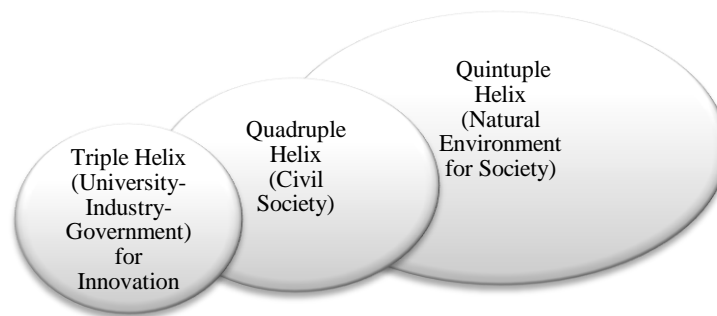
biotechnology, material science and telecommunications. This study suggests that knowledge spaces can be relevant in the generation of innovation within the triple helix experiences in Mexico. The formation of knowledge networks among public research centers, regional companies, their international counterparts, and Mexican farmers, was crucial for collaborative research and learning. This interaction did not necessarily mean a radical innovation, but rather a network of support focused on a particular technological project. Moreover, the triple helix model is a new mode of innovation in Mexico, and is expanding to other regions (Casas et al., 2000).

### **2.9.2 Quintuple Helix**

The triple helix represents a trilateral network of university-industry-government relations to produce knowledge and innovation, but it lacked certain important elements necessary for innovation across a broader spectrum of application areas, particularly sustainability. The fourth helix introduces culture and civil society. The fifth helix includes the natural environment. Quintuple helix innovation systems introduce the concept of sustainable competitive advantage for nations and regions through science and technology. This advantage consists of the creation and support of technology enterprises for sustainable innovation. Hence, multiple regional players should encourage and support the creation, transfer, and commercialization of scientific and technological innovation for sustainability (Carayannis & Campbell, 2012). Sustainable innovation is an alternative for technology and knowledge related to social, environmental, and economic factors that impact society (Seyfang & Smith, 2007). This innovation system focuses on higher learning processes, and new dynamics between top-down and bottom-up players including government, university, industry, civil society, and grassroots initiatives to cooperate in an intellectual and more efficient way (Carayannis & Campbell, 2012). However, technological innovation has a social and environmental impact; thus, more attention on production and consumption systems is necessary (Kemp, 2010).

The quintuple helix represents innovation networks and knowledge clusters where human, social, financial, technological, and cultural elements co-evolve, innovating for sustainability (Carayannis & Campbell, 2012). This model is based on values,

multiculturalism, and creativity. The creativity leads to knowledge creation and collaboration because people are involved in producing ideas for innovation. For this reason, Carayannis and Campbell (2012) propose the quintuple helix as a framework for transdisciplinary and interdisciplinary research in support of sustainability. Research and entrepreneurial activities carried out by universities along with other players, are usually linked to research, development, and markets; as a result, the opportunity for learning and transferring sustainable knowledge and technology is set (Carayannis & Campbell, 2012). Figure 2-2 shows the evolution from triple helix to quintuple helix.



*Figure 2-2. Co-evolution from triple helix to quintuple helix (Carayannis & Campbell, 2012).*

Leydesdorf (2012) argues that the triple helix is already too complex to consider adding another helix, whether civil society OR ecology, to a model of innovation. As well, every transition from one economy to a new economy is made progressively more complex; a fourth or fifth helix is only necessary when this element plays a crucial role in a particular national economy (Leydesdorf, 2012). However, with civil society as the fourth actor of innovation, it seems necessary for applications of innovation for sustainability. Civil society can proactively participate in innovation and still be aware of the environment. The disadvantage of these innovation systems is that there is little research and few empirical studies examining the application of the triple and quintuple helix models. Also, the quintuple helix is a new sustainability focused innovation model that natural fit for agricultural applications. There is not enough specification of functions or relevant outcomes to conclude what components are contributing positively to sustainability.

## **2.10 Sustainability and Innovation in Higher Education Institutions**

One of the objectives of Higher Education Institutions (HEIs) should be to invigorate the regional economy and local welfare (Caniëls & van den Bosch, 2011). Patents, employment, and technology commercialization are some of the impacts of HEIs have on regional development and economic performance. With dynamic and evolutionary innovation processes, HEIs are involved in learning interactions along with other players that have diverse values and routines at different scales. In this sense, Porter (1990) recommended the development of technology clusters and called for national and regional governments, universities, and private sectors partners to shape their own comparative advantages through niches that develop and commercialize higher technology. However, HEIs as technological centres, or niches, should also emphasize their role in knowledge creation and social good, aside from marketable outcomes (Bubela & Caulfield, 2010). Thus, HEIs should reassess their role in the innovation systems that support sustainability by generating new knowledge and ideas based on regional well-being.

Universities as knowledge hubs play an important role in the economy (Breznitz & Feldman, 2012; Youtie & Shapira, 2008). Breznitz and Feldman (2012) suggest that knowledge transfer, policy development, and economic initiatives are the functions of universities. Knowledge transfer involves research, skills, and learning experiences within and outside HEIs. Some formal and informal mechanisms are used to transfer knowledge to society. Formal mechanisms include: patents, licenses, and sponsored research agreements with companies or industries. Informal mechanisms are faculty consulting, the hiring of students by industry, and transferring knowledge through social networks. Policy development involves the identification of a community's needs, doing research that provides analysis and reports for policy recommendations, and decision making in support of economic development (Breznitz & Feldman, 2012). Economic initiatives include developing talented workers, partnerships, and community development. Workers participate as knowledge providers and recipients, through programs such as traineeships, internships, and seminars. Community development refers to the involvement of HEIs in economic and social projects for the improvement of local and regional communities



(Breznitz & Feldman, 2012). For example, in 2003, the Center of Innovation program in the state of Georgia was established to face the needs of standard metropolitan areas and research universities. As a result, the industrial extension service attracted researchers and academics from Georgia Tech, as well as government laboratories, to create a regional partnership to address environmental problems with local industries (Youtie & Shapira, 2008).

Sustainability transition in HEIs implies a new understanding of changing processes. These changes include structures, practices, and the connection between them. HEIs can contribute to sustainability transition through planning and managing processes and internal organization to improve their service, facilities, technology, and innovation (Robinson et al., 2011). Similarly, Cortese (2003) and Lozano (2006) state that HEIs should include courses and curricula, basic and applied research, campus operation, community outreach, as well as evaluation and reporting. Discovering new innovative practices and technologies through their colleges and research units is an additional benefit realized by the HEI; furthermore, involving students and researchers from different disciplines can create new pathways to sustainability (Carayannis et al., 2012). Vergragt and Brown (2007) suggest that experiments and projects allow for a focus on better solutions for environmental, social, and economic factors. For this reason, HEIs should take action on societal problems sharing technological and sustainability expertise in collaboration with local actors (Robinson et al., 2011). HEIs are not usually seen as higher technology producers, mainly due to capacity issues. This is especially a view held by providers of venture capital; and additional concern is the potentially inappropriate use of public funding to support the high costs of technology developments (perhaps for sustainability) (Smith et al., 2010). However, this situation should not prevent universities from being part of sharing knowledge and technology through collaborative and transformative learning. Unfortunately, there is little research on how interactions between HEIs and other players are shaped and what other aspects of innovation within HEIs toward sustainability should be studied (Caniëls & van den Bosch, 2011). As such, analyzing innovations supporting sustainability within HEIs and communities is needed.

## **2.11 Contextual Setting: Agriculture**

The importance of agriculture in addressing food security and other natural resource issues, such as soil quality and water quantity, has attracted the attention of diverse stakeholders. The World Bank has pointed out the significance of agriculture based-economies and small-scale agriculture in reducing poverty, particularly in developing countries. This situation allows small farmers to improve productivity, profitability, and sustainability for economic development (World Bank, 2008). Attention to agriculture should be of national importance to ensure food production, allocation, and fair incomes. Farming not only involves production processes, but also the use of resources. “Farming is an activity (of Man), conducted to produce food and fibre (and fuel, as well as many other materials) by the premeditated and controlled use of plants and animals” (Spedding, 1988, p.5). In this way, agriculture is a large action that involves people in communities, productive goals (products and profits), and the contribution of diverse disciplines to deal with actual situations and problems. Farming can also be defined as a system because it includes complexity, change, adaptation, and continual restructuring as necessary. It is a holistic system of social, technical, economic, and ecological factors that interact and contribute to better farming performance. Science and technology have influenced agricultural systems through technical knowledge and innovation; however, challenges exist. To ensure global food production, a modification in the generation and transfer of knowledge, as well greater learning interactions are needed if we prefer sustainability and innovation.

### **2.11.1 Agricultural Innovation System**

Innovation in agriculture is multifaceted. It includes the interaction of different players for the generation and exchange of agricultural knowledge to improve economic conditions and raise productivity. Agricultural innovation systems are complex and include interactions between different institutions regarding how individuals and corporations learn to learn, learn to change, and learn the socio- economic conditions of each of the parties involved (Spielman & Birner, 2008). While these interactions have led to the development of technologies that have a positive impact on agriculture production and better agricultural

practices; it is also true that such technology is not available to all farmers and will not solve all sustainability problems (Clark, 2002). Agricultural education, research, and extension services can foster technological innovation to reduce poverty, increase food security, and stimulate economic development. An agricultural innovation system framework was developed by Spielman and Birner including the farmer as a player engaged in a complex network of innovation, formal and informal institutions, and policy incentives motivating innovation processes. These players have begun to interact for the expansion and diffusion of specific agro-products. However, critical issues need to be addressed, including more aligned public policies between innovation and technology (Spielman & Birner, 2008) contributing to agriculture and sustainability.

While development of agriculture has been associated with technological innovation, innovation in agriculture has begun to increasingly manifest itself through social and institutional innovation. For instance, networks among HEIs, producers, and markets have emerged to exchange ideas and methods. Innovation in agriculture has been associated with knowledge, education, and business practices; in addition to political channels, extension services, and stakeholder networks to transfer knowledge and technology. Social innovation can also be considered a part of agricultural innovation system both formally and informally, including local farmers groups and cooperatives (Snapp & Pound, 2008). Agricultural innovation can be based on formal research and informal experiments generated by farmers. The authors describe three approaches to agricultural innovation as:

- Technology transfer. Technology developed and adapted by researchers and transferred to farmers through extension services.
- Farmer first. Farmers generate, coordinate, and evaluate agricultural technology based on their own local practices.
- Participatory learning and action research. Researchers help groups of farmers develop their knowledge and abilities for self-progress, while providing guidance and support.

Chave et al. (2012) analyzed the agricultural innovation system concept through the study of twenty seven joint technological networks in France. The results show that interactions among institutions, stakeholders, and innovation products should be seen within

institutional arrangements, dynamic strategy, and the innovation capacity of a country. The authors emphasized the transfer ability of a technology includes unpredictable contexts, shared vision of challenges, learning processes, and a transition from top-down to an interactive innovation approach.

Cannarella et al. (2011) state that validation of practices and techniques from traditional knowledge can be incorporated into Western science to re-invent technology for the progress of local communities. This process is known as traditiovations. Traditiovations tends to involve the storage and sharing of knowledge by a local community and expressed through formal communication. Likewise, the authors propose concepts to promote the assimilation of innovative technology for sustainability: enhancing local confidence and respect for local knowledge, in addition to supporting the broad and creative use of local materials. For instance, farmer-scientist collaborations are relevant to innovations in practice and technology. There are five topic associated with optimizing the collaboration between farmers and scientists for technological innovation: a) user direction, to set the positions of stakeholders and the priorities of the field; b) western science being open to assimilating informal knowledge held by farmers; c) the casual modes of testing use according to the capacity of the farmer for experimentation and dissemination; d) the externalization of implicit knowledge held by farmers to be transferred or used by others; and e) economic considerations for farmers who give their time to research initiatives (Hoffmann et al., 2007). This is an example of how important learning interactions and knowledge transfer among local farmers and scientists are for agricultural innovation systems.

### **2.11.2 Agriculture and Sustainability**

The agricultural system involves difficult and unpredictable situations. For this reason, exploring and analyzing new practices, knowledge, and technologies that do not have social and ecologically negative consequences are important. Sustainability in agriculture is usually associated with agro-ecosystem management. Agro-ecology considers some aspects of sustainability including biodiversity, resource efficiency, productivity and economics,

and farm system resilience (Snapp & Pound, 2008). Biodiversity includes both plant and community diversity at larger scales. Diversity supports pest control and healthy crops. Resource efficiency is related to the use of recycled nutrient resources and energy and reducing the use of non-renewable resources and expensive inputs. Economic return in farming is just one aspect of productivity and economics; however, in order to support sustainability it is necessary to assess the cost and type of inputs as well as access to local technology and seed systems in the long term. Resilience in agriculture means how a farming system reacts to disturbances. The prevention of soil erosion is vital to building agricultural resilience; thus, soil quality is important to the long term farming system. However, agro-ecology has not been connected to growth and development goals because more incentives and policies are oriented to the development of genetic engineering (Vanloqueren & Baret, 2009).

Gliessman and Rosemeyer (2010) illustrate that farmers and producers are moving to better practices in agriculture that not only bring economic benefits, but also contribute to environmental sustainability for agriculture in the long term. Some factors facilitate this transition, including: a) energy cost uncertainty, b) the generation of new viable practices such as organic agriculture, c) an increase in environmental awareness, and d) a need to integrate livelihood and conservation in agricultural communities. These factors help transform diverse scenarios for environmental sustainability, but also help integrate other dimensions of sustainability for better farming communities by offering improved products, low cost of production, and increased quality of life.

Innovative agriculture for sustainability is understood as the interaction of several dimensions. The productive and primary sector must be economically viable, with fair incomes. As well, quality of life and equity for the protection of human and social development of local individuals must be considered. For instance, fair trade is a social movement that improves the life of farmers and promotes environmental issues by certifying traders in relation to environmental standards for the production of farming products (Phills et al., 2008). Ecological justice must also be incorporated, ensuring biodiversity and land responsibility, healthy crops, and respect for balance in natural life

cycles. A case study was conducted in the Ayuquila River watershed in Jalisco, México by Martinez et al. (2006). This case study is an example of how universities and society can be integrated for social development and natural resource conservation. The authors found relevant societal contributions by universities integrating scientific and local knowledge. Martinez, et al. (2006) concluded that the stakeholder-wide search for needs and solutions to social and ecological problems; as well, improving the collaborative processes can aid in the achievement of sustainability in local communities.

Aerni (2010) conducted a study to demonstrate how new technologies endanger the social and environmental sustainability of domestic agriculture in some European countries due to the popular beliefs of people. For instance, two surveys on sustainable agriculture were conducted with stakeholders in Switzerland and New Zealand. The results indicated that political interests and attitudes influence the role of technology in promoting sustainable agriculture (Aerni, 2010). In Switzerland stakeholders considered technological change as a hazard to sustainable agriculture; however, in New Zealand, stakeholders believed that economic and technological change is a necessity. A study conducted by Pretty et al. (2006) analyzed 286 agricultural projects in 37 developing countries to determine the range of sustainable farming technologies and practices. The researchers found that low-cost technologies and inputs improved local crop effectiveness and had a positive impact on water use, carbon appropriation, and pesticide use. These practices involved farmers and local communities incorporating better use of external technologies and non-renewable resources. Despite these studies, the relationship between sustainability and innovation in agriculture has been approached narrowly.

## CHAPTER THREE RESEARCH METHODOLOGY

### **3.1 Description of Research Methodology**

In this research, the consideration of diverse knowledge holders involved in innovation and sustainability beliefs and actions will be the focus. Murphy (2011) proposes an interdisciplinary research framework, which supports the cross-cultural perspectives associated to multiple disciplines and types of empirical knowledge. For instance, scientific refers to knowledge based on western scientific methods. Observation is related to knowledge based on experience and beyond scientific facts (e.g. farming practice). Ethical refers to the knowledge based on good, right, bad, or wrong and has a foundation in social morality. Aesthetic refers to knowledge based on art and beauty. And instrumental is related to knowledge based on application and practical methods. The subjective and diverse meanings developed by individuals through their experiences are related to the social constructivist worldview (Creswell, 2009). This approach refers to understanding knowledge as influenced by the perceptions and values of different players, where the truth is seen through a range of lenses, thereby changing reality through subjective experience, value, and knowledge. In this sense, to understand problems and constraints in a community it is essential to have a deep knowledge of the institutional environment, as well as an understanding of local knowledge, perceptions, and the ideas of key players and institutions involved (Ostrom, 2010). Also, the constructivism paradigm helps create multiple perspectives and options to be evaluated by social groups about learning and knowledge for sustainability and innovation, which are embodied by a holistic integration of actions, creative ideas, and collaboration (Geels, 2010).

This chapter reports the methodology and research design based on the preceding literature review and theoretical framework. This research introduces a qualitative methodology to empirically reveal the contribution to our understanding of innovation for sustainability through the analysis of the body of data collected in the field. Qualitative methodology stresses the connection of research participants with the social reality involving their own interpretation and understanding. A qualitative case study with a multi-methods approach to

explore learning interactions, innovation and sustainability actions, and beliefs of key stakeholders was conducted. The case study approach provides an opportunity to evaluate persons, institutions, and other phenomena (Yin, 2009). A multi-method approach can be used to suit each case study to support data collection and data analysis, as well as to understand other scenarios in the study (Yin, 2009; O'Leary, 2010). My case study was holistic, using both a bottom-up and top-down methodology, with the goal of identifying the perceptions, problems, and interests of stakeholders involved. Using a bottom-up approach means to include those stakeholders who usually are not considered and do not express their opinions, ideas, and experiences. It is to build a more holistic case study through connecting and empowering the bottom line people as important elements in a system and have the opportunity to listen their voice. Yin (1993) states that case studies analyze complex social phenomena within its real-life context and are a useful tool for studying the gap between phenomena and context. The generation of information derived from different groups to identify the variation of perceptions, experiences, and situations on a particular context is a case study. A case study allows the examination of a complex system in more detail because both case study and complex system are in a dynamic and constant evolution, and diverse aspects and elements need to be considered including people, learning, and adaptation (Stake, 2006).

This research was intended to study conflicting aspects within a specific area with multiple contexts (cultural, institutional, and political). As well, I wanted an in-depth understanding of sustainability, the contribution of innovation to sustainability, and the challenges of building local innovation system, including the association of local players in learning and innovating for sustainability. I focused on people, place, programs, and policies to understand and identify those conceptions, opportunities and barriers to build dynamic knowledge networks and learning interactions. The complexity of this particular phenomenon required a case study methodology. This methodology involves contextual variation inside communities, institutions, and social interactions. Using the case method accomplishes several goals: exploration, theory building, theory testing, and theory extension (Eisenhardt, 1989; Pettigrew, 1990). In this sense, the case method that has guided this research methodology has supported a deeper understanding of innovation for



sustainability. The research topic (the contribution of innovation to sustainability) is focused on the selection and development of theory, which has supported explaining how stakeholders generate, apply, share, and disseminate innovation efforts for sustainability. In other words, this research focuses on understanding the current dynamics, allowing me to develop specific concepts related to innovation for sustainability (Meredith, 1998; Hernández et al., 2010).

To observe the reality of a case, the researcher must develop skills as a historian, sociologist, and economist, and have a good attitude to inquire about new discoveries (Hernández et al., 2010). Using the case study methodology has the advantage that researchers can make comparisons with other cases, carry out an assimilation of descriptions (Yin, 1993), and enrich our understanding of how innovation can contribute to sustainability. A qualitative methodology is a way of examining the empirical evidence collected in the field. It is intended to ensure a narrow margin between the data and what people actually say and do. It is observing people in their daily lives and listening to what they have in mind; as a result, the qualitative researcher obtains direct knowledge of social and institutional life (Yin, 1993). According to Hernandez et al. (2010) qualitative methodologies are inductive and holistic. Researchers develop concepts and understanding based on patterns of data and not collecting data to evaluate models, assumptions, or hypothesis. As well, researchers see the context and people in a holistic perspective; people, scenarios, or groups are not reduced to variables, but they are taken as a whole.

The qualitative research process involves the generation of meaning from data collected through the interaction with and involvement of participants (Creswell, 2009). Some characteristics of qualitative research are: a) exploratory and descriptive, b) data collection is conducted in a natural setting, c) collection methods are interactive, d) the approach is not a numerical measurement or does not apply statistical methods e) the researcher focuses on a specific context, analyzes, and interprets what he finds based on his own experience and background (Creswell, 2009; Hernández et al., 2010). The researcher uses various research techniques, aspects of reflection, and social skills to study phenomena and situations (Neuman, 1994). The multiple sources of data collection are selected according

to the contribution of information, an understanding of the phenomenon, and whether these sources provide different perspectives on the research topic (Hernández et al., 2010). For this reason, qualitative multiple data collection methods were selected because it was necessary to be open and document people's interpretations and perceptions inside their spaces and activities, as well as recognize diverse situations, practices, and beliefs. Rather than state an assumption or create a testable hypothesis in a controlled environment, qualitative evidence had to be gathered and analyzed in terms of real life experiences and knowledge. In general, this case study was exploratory and was intended to illustrate lessons that may be significant for diverse economic sectors and policy makers regarding the contribution of innovation to sustainability.

### **3.2 Study Area and Rationale**

The field study was conducted in the Yucatán Peninsula of México, in the communities of Conkal and Merida over a period of three months in 2013. The selection of this participant community as part of this research was due to the nearby location of one higher education institution (HEI) surrounded by local vegetable farming communities, notably those planting habanero chiles. The habanero chile has become an increasingly popular product in the world, and one of the largest producing areas is the Yucatán Peninsula.

The state of Yucatán is composed of calcareous and rocky soils, has a network of underground rivers that flow into the ocean, and its predominant vegetation is tropical rainforests. The state has an important natural capital, but this has been reduced due to agricultural and livestock activity, human settlements, and the effects of hurricanes. Agriculture is the main source of income for rural communities who grow for their own consumption and for capital generation in the state (OECD, 2007). One of the environmental risks is the land degradation due to the loss of biological and economic productivity. Horticultural production in Yucatan is divided into three areas:

- Family Producers. Most of their production is for home consumption and the rest for the local market. They use stony soils, temporary plots, and production diversity as a means of subsistence. Most of these producers work the traditional milpa (a traditional farming system).

- Small and medium producers. They access to governmental support, have links to commercial agents and industries. They handle a mixed system (between traditional and scientific).
- Large companies. They have high economic and technological capacity to supply an external market. They have a mechanized production system, but they are starting to consider organic farming including greenhouses and hydroponics.

In the Conkal community and surrounded areas these types of producers are located, which use about 35% of the land for agricultural activities. Family farmers are those with fewer yields because their production has declined in recent years by various factors including the intergenerational problem among family members (new generations prefer to study or work outside farming), costs and risks to plant, and a lack of access to public and private resources (Fundación Produce, 2011).

The Yucatán habanero chile covers 80% of the total production in Mexico. Over 50% of this production is dedicated to planting native seeds in the region. The market for this product is very demanding, which involves the use of technology to ensure high productivity, performance and quality. 50% of producers use low-technology, do not use fertilizers, and produce under temporary. 30% of them apply fertilizer and water at critical periods. 20% of producers have pest control, provide continuous irrigation and clean their plots. Some of the problems encountered in planting this product are: plant health problems (whitefly) and defoliating pests, which increase the risk and cost of production for farmers (Fundación Produce, 2011). The habanero chile production chain is a priority for the state because it involves two economic sectors (agricultural production and agribusiness). In 2001 a civil association called Yucatán habanero chile was created in order to achieve greater competitiveness by taking advantage of collaborative work including access to current technologies and knowledge in order to offer the product to diverse markets. In 2003 the production network for the development of the Yucatán agribusiness was founded to leverage resources through synergy from farmers associations and public and private institutions. Participants in this network are HEIs, research centers, federal and state governments, producers, traders, and individuals. In fact, there have been studies considering the economic and market aspects of this product system, and how

biotechnology and agronomy has contributed to the development and conservation of native and hybrid seeds (CONCYTEY, 2004). For instance, the Technological Institute of Conkal was my university example because researchers, alumni, and students generate and transfer scientific and technological knowledge regarding this product system (habanero chile) that can also contribute to innovation and sustainable systems. The Mexican national innovation system is composed of major players such as universities, public research center, government institutions, enterprises, and financial institutions. The agricultural research system in México is mainly constituted by the Fundación Produce, Conacyt, universities, research centers, Inifap, and product system committees. In fact, the Mexican National Development Plan 2013-2018 provides the scientific, technological, and innovation actions as pillars for social progress and sustainable development. For this reason, greater efforts to enhance and consolidate university-industry-government-civil society-natural environment relationships are required in local and regional communities. Thus, I point out how this relationship is taking place, in that particular region and product system, by means of an empirical case study.

In 2004 the provincial product system committee of Yucatán habanero chile was constituted in compliance with the provisions of the Law on Sustainable Rural Development issued in 2001. Some objectives of this law are: a) promote the social and economic welfare of producers, their communities, and agents of rural society, b) promote the conservation of biodiversity and improving the quality of natural resources, c) value the various economic, environmental, social and cultural functions of the different manifestations of domestic agriculture. This law includes the planning and organization of agricultural production, industrialization, and marketing in order to improve the quality of life of rural communities. In this sense, the integration of a habanero chile product system was composed of HEIs, research centers, industry, government, and producers to promote and consolidate the production and marketing of the product. “A product system is the interaction of various economic agents for profitability according to the production, distribution and consumption of a product designed for an internal and global market (Consejo Nacional para la Producción del Chile, CONAPROCH, 2014).” Through policies, actions, and programs the government has tried to promote social and economic welfare of

rural producers, as well as promote the conservation of biodiversity. Every year this organization presents a progress report on its achievements regarding environmental conservation and the involvement of farmers in the economic and social farming system, particularly smallholders. However, this organization recognizes that the habanero chile product system is still working to achieve all objectives of the law (CONAPROCH, 2014).

As a result, a joint project called "the original certification of the habanero chile" was established in 2005. More than 35 researchers, an industry and the provincial government were working to get this certification. One of the components of a case study is defining the unit of analysis for the research. In this research the Technological Institute of Conkal (TIC) was the HEI; it has strong linkages with other multiple local stakeholders (agro-industries, farmers, and government authorities) involved in joint projects, education, extension, and business. This institute was established in 1974 and is one of the institutions participating in research and innovation; it also helps develop projects of technological innovation focused on the horticultural sector in an environmental sustainability and socially equitable framework. The TIC is part of "SNEST" (Sistema Nacional de Educación Superior Tecnológica, which translates to national system of higher technological education). This national system considers part of its mission to be a commitment to the promotion of sustainable and regional development. All programs and actions carried out in TIC should be aligned to the development national plan 2006-2012 and 2013-2018. This plan is a mandate for all public institutions. The TIC has seven undergraduate and two graduate programs and has been part of the community for thirty-eight years. This institute has been involved in collaborative processes with other institutions and companies for knowledge generation, to benefit farming communities in the region, and has been dedicated to agricultural technology research. A PhD program in sustainable tropical agriculture is offered in TIC. This program focuses on research projects and technological innovation for the sustainable use of genetic plant resources. In the case of the habanero chile, the institution has taken more than 10 years developing research in a variety of topics such as morphological characterization of 34 collections of habanero chile, variation in populations of native habanero chile, improving the productivity of habanero chile, the assessment of germplasm habanero chile in different environments around

Yucatán, seed germination in five habanero chile conditioning treatments , among others. Moreover, in the last four years the TIC has had students and professors participating in the National Technological Innovation Event; an event intended to foster the development of technology innovation for products, processes, and services through the application of technology toward sustainability goals. Projects come from a wide array of topics including water, agriculture, food, telecommunication, energy, health, and transportation.

In 2006 the State Council of Yucatán chile producers was formed with the aim of developing the supply chain holistically, through a better coordination between producers, manufacturers, retailers, and consumers. The challenge for this council was to implement productivity and production quality by covering sustainability and environmental protection criteria. In 2008, the state of Yucatán developed a strategic plan to promote progress in various areas such as health, energy, education, and food. The habanero chile as vital food for internal and external market, has received all kinds of support, including financial and intellectual capital, infrastructure, and farming public programs. This strategic plan proposed the objective of promoting science and technology as a political tool to serve the needs of the population (Fundación Produce, 2011). In this way, a system of research, innovation and technological development was born the same year. This system was based on the triple helix model, which is considered as the center of innovation and development to drive the production of new knowledge. This model involves research centers, universities, industry, and government that are the engine to induce regional development. In this regard 10 public institutions (HEIs and research centers) came together to create synergy and foster capacity building to create the Yucatán system of research and innovation (Consejo de Ciencia y Tecnología de Yucatán, CONCYTEY, 2009). The collaboration for generating and applying knowledge and a spirit of wills between HEIs, research centers, and industries to promote innovation to support social welfare is the basis of such system. My study was based on an empirical work conducted with multiple stakeholders inside product system ‘habanero chile’ in the Merida and Conkal community, mainly with stakeholders from the TIC. This study examined whether the conditions exist within the product system that would lead to a quintuple helix model. This model as a system of innovation comprises learning networks where new dynamics between top-down

and bottom-up players are associated for producing ideas and knowledge for sustainability (Carayannis & Campbell, 2012).

The geographic and historical summary of habanero chile production suggests the need for working relationships among the diverse local players. As well, the foundation of the research and innovation system in Yucatán provides useful information about the importance of dynamic integration and collaboration among various regional players in the development and promotion of habanero chile and other farming products. Agriculture is an important part of this economic system as it serves as food production for humanity. Although dominant practices are still being applied, it is clear that new and better practices are emerging, both in Yucatán and around the world. Food and agriculture are globally important; therefore, it is important to study local food production systems (Norberg-Hodge et al., 2002). Before analyzing the structure and dynamics of this system, through a local HEI and its relationship with local players as a case study, it is vital to describe who the stakeholders are and how they participate in this product system.

- Alumni. Most alumni are working on research and development, one is a consultant, another is working as a governmental soil consultant, and a third is a producer.
- Researchers. They work on basic and applied research. Research topics include: Plant genetic resources, plant metabolites, microorganisms, plant waste, pathology/pathogens, irrigation systems in tropical areas, and organic substrates. Their average tenure in research is 10 years, most work by governmental invitation to be part of the habanero chile product system.
- Executives. They work as a liaison in governmental, private, and public institutions. They have been involved in habanero chile projects and programs because they can mobilize resources, promote initiatives and incentives, look for new markets and network opportunities, and plan and diffuse programs and policies.
- Farmers. *Small* farmers are usually measured by mecate (approximately 20m. x 20m.). Two farmers plant between five and six mecates, the other plants three mecates. They produce at opencast lands (without using greenhouses), and their farming technique is a mix (traditional and scientific). *Intermediate* farmers have between fourteen and eighteen mecates (approximate between 5,000 and 10,000

m<sup>2</sup>). They use greenhouses to reduce the use of agrochemicals, but also they can produce at opencast. Most of them are TIC alumni.

Describing the participants help identifying how the interaction among them impact on the dynamic of a local innovation system (product system).

### **3.3 Data Collection**

This research used purposive sampling, also known as theoretical sampling, where stakeholders were chosen according to specific criteria, explained above. The data were collected through formal and informal individual and focus group interviews. To supplement data I also carried out a document analysis, and a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis.

#### **3.3.1 Document Analysis**

A document analysis of policies and planning with respect to innovation processes, agricultural technology, and sustainability was conducted to provide contextual and historical data for this research. In this case study the analysis of documents is valuable to support other qualitative methods (Bowen, 2009). The document analysis helps to identify new research questions, verify findings, and gather additional data (Bowen, 2009). All types of documents have the potential to help decode meaning, reveal significant information, and add understanding to the research purpose (Merriam, 1988). The ultimate goal is to examine policy incentives and mechanisms that encourage HEIs, farmers, and other local-associated players in the generation of innovation and technology to sustainability. I reviewed national, regional, and local technological innovation regulations, and programs. Technological innovation programs for agriculture and sustainability policies from the past 4 years were collected. From this, a retrospective analysis of programs and policies related to the study were carried out to evaluate their opportunities and barriers in building local innovation systems. The document analysis focused on processes and outcomes of technology innovation in agriculture, knowledge transfer, and how these are related to social, economic, and environmental aspects. This analysis involved organizational manuals, documents, and reports of a national system of higher



technological education, the agricultural sector, national and regional development plans, as well as national technology and innovation programs. Table 3-1 indicates the list of documents selected based on their implications across diverse scales and the identification of a possible contribution of innovation to sustainability.

Table 3-1  
*Documents*

Agrifood Information Service, SAGARPA, México	Special Program of Science, Technology and Innovation 2008-2012. CONACYT, México.
Research policies, technology transfer and innovation for rural sector 2007-2012. SAGARPA, México.	Technological Innovation Agenda of Yucatán 2011.
Sustainable Rural Development Act of Mexico 2001.	The conditions for innovation, technological development, and the entailment of production in Yucatán 2010.
State Office of Information for Sustainable Rural Development in Yucatán. (Statistics and Data)	National Development Plan of México 2007-2012, and 2013-2018.

### 3.3.2 Stakeholder Analysis

Stakeholder analysis focused on the significance of stakeholders, their perceptions of benefits and problems of collaborating with other relevant players, as well as their participation in local innovation systems in support of sustainability. Stakeholder analyses offer background information useful to understanding the dynamics of the policy processes (Runhaar et al., 2006). For this research, “A stakeholder is any entity with a declared interest in a policy concern” (O’Leary, 2010). Stakeholder participation involves individuals and institutions that are embedded in an intervention (Mikkelsen, 2005). Stakeholder participation can be classified into three levels: primary, secondary, and key stakeholders. The primary stakeholders are individuals who are affected directly by a program or a public policy intervention. The secondary stakeholders are the intermediaries involved in that policy intervention. The key stakeholders are individuals or groups who may influence policy-related decision making (Mikkelsen, 2005). In addition, there are four

characteristics for stakeholder analysis: the position, the level of influence, the level of interest, and the group to which they belong (O'Leary, 2010). The objective for using this method is to analyze learning interactions among multiple players, and to examine formal and informal ways to create and transfer knowledge for sustainability.

Caniels et al. (2010) suggests asking decision makers about how collaborative groups work together to enhance innovation and translate knowledge for community development. These decision makers will also provide insight into internal motivation and the perspectives of these groups regarding how sustainability is seen through the lens of innovation, what innovative technology for sustainability they have created, and how and why they have interacted with other relevant players. For this reason, I collected stakeholder data through interviews. Interviews are dialogues between two individuals, controlled by questions and answers (Eriksson & Kovalainen, 2008). Usually, this method seeks open-ended answers relevant to the larger research objective (O'Leary, 2010). Three types of interviews are available for consideration: structured, semi-structured, and unstructured (in-depth interviews). The in-depth interviews have the ability to combine structure, guide, and flexibility allowing natural conversation with the interviewee. The main advantage of this type of interview is the remarkable and sudden information or set of opinions that may appear during conversation (O'Leary, 2010).

In-depth interviews with key players were conducted at three governmental scales: regional, institutional, and local. In-depth interviews were carried out one-on-one/face-to-face, and lasted 50-80 minutes, to allow flexibility for changes in the direction of the interview and expansion towards further topics of interest developed during the interview. The interviews were conducted in Spanish as this is the mother tongue of the participants. Interviews, transcriptions, and translations entail a transformation of sound from recordings to text (Duranti, 1997). Also, transcripts of interviews were completed in Spanish. This helped me analyze in more detail the information in my own first language. This included a process of repeated examination. Yet, the complexity of translation is notorious. Translating from one language to another implies inherent challenges and often requires the use of translators (Duranti, 1997). Seidman (2006) comments that translating involves great

complexity, authenticity, and information care. The translation from Spanish into English was done by the researcher; therefore a translator was not required. However, one implication was that I could not find the exact translation of some words, which means I had to deal with the issue of biased translation. Nevertheless, the replication of most original expressions of participants was considered. A “free” translation seemed to be more reasonable for this research when creating quotations. According to Filep (2009) in a “free” translation, a readable quotation can include changes in structure and some words in order to make the quote clear and understood by readers. In this sense, I presented most quotations of participants through the interpretation of their thoughts, not using literal translation (word-by-word). This was not intended to misinterpret or reinforce the original material. Local and cultural realities were another implication. These are related to language, which incorporates values and beliefs (Duranti, 1997). Thus, culture and local traditions and use of language have to be included as part of the analysis. The fact I am from the region meant I share some cultural and linguistic knowledge with participants, except the Mayan people. Although most participants and I share the same history and traditions, Mayan farmers have their own historical and cultural perspectives. They interpret and see the world differently. For them the meaning of various concepts might be quite different. This situation may represent a disadvantage when conflicts in knowledge of traditions might emerge during interviews (Filep, 2009). However, this situation did not seem to happen.

This analysis involved interviews with ten executive stakeholder interviewees including governmental and institutional top-level representatives in the Yucatán Peninsula, as well agricultural associations and industries. In addition, four personal interviews with farmers (two Mayan smallholders, one small, and one intermediate farmer) were also conducted; these participants were identified using a snowball sampling technique, as they were not able to participate in a focus group, as illustrated in table 3-2. The interviews focused on gathering individual perspectives and understanding of local innovation systems, sustainability, and the interactions of learning and collaboration (formal and informal). These helped to identify technological and non-technological innovation. As well, through these interviews I could examine policy incentives and mechanisms for the development or

improvement of innovative technology by considering the social, economic, and ecological benefits of such innovation, specifically in habanero chile production.

In-depth interviews with primary and secondary players were also conducted with the following sample: seven researchers from the TIC, two researchers from the CICY (Scientific Research Center of Yucatan), and one researcher from the Technological Institute of Merida. These researchers have been involved in habanero chile plant breeding research, and have participated in regional development projects supporting local agricultural communities and sustainability. Moreover, three individual alumni interviews were conducted due to the lack of time to meet together in a focus group. One of them is working as an expert farming consultant, another alumnus has his own farm, and the last alumnus is in a governmental institution as an expert on vegetable sanitation. The purpose of these interviews was to analyze interviewee motives, incentives, and learning processes. As well, the mechanisms and policies they are familiar with in the transfer of knowledge and technological innovation to the farming sector supporting sustainability was important. An important purpose is the identification of a new role of HEIs into innovation supporting sustainability. Siegel et al. (2003) state that interviews with stakeholder groups of this type provide detailed information regarding what needs to be explored in the field study.

### **3.3.3 Focus Group**

The data generated by the interaction of various players were carried out through focus group interviews. Participants in group interviews manifest their own views and experience, but they also listen and reflect on other comments said in the meeting (Ritchie & Lewis, 2003). Two focus group interviews with alumni and intermediate farmers, as shown in table 3-2, were conducted to explore learning processes, identify the creation of new or improved knowledge and technology innovation, and examine the understanding of sustainability through the lens of innovation.

Table 3-2  
*Participant Pool*

Stakeholders	Number of participants	Type of Method
Executive Stakeholders: <ul style="list-style-type: none"> <li>- INIFAP (The National Institute of Forest and Agricultural Research) Liaison Chief</li> <li>- Council of Science and Technology Director of Yucatán (Concytey)</li> <li>- Rural Development Secretary Representative of Yucatán</li> <li>- Municipality Mayor of Conkal</li> <li>- Chile Habanero de Yucatán, A.C. Representative</li> <li>- Executive of Promotora Agroindustrial de Yucatán</li> <li>- Executive of Fundación Produce de Yucatán</li> <li>- Executive of El Chixchulub</li> <li>- Technological Management and Liaison Chief at the Technological Institute of Conkal</li> <li>- Scientific Research Center of Yucatán (CICY)</li> </ul>	1 1 1 1 1 1 2 1 1 1	Interview/SWOT Analysis Interview Interview Interview Interview/SWOT Analysis Interview Interview Interview/SWOT Analysis Interview
Alumni The Technological Institute of Conkal	7	Interviews 1 Group Interview 1 Alumnus in SWOT Analysis
Researchers: <ul style="list-style-type: none"> <li>- The Technological Institute of Conkal</li> <li>- Scientific Research Center of Yucatán</li> <li>- The Technological Institute of Merida</li> </ul>	7 2 1	Interviews
Farmers: <ul style="list-style-type: none"> <li>- Small farmers (2 Mayan farmers)</li> <li>- Intermediate farmers</li> </ul>	3 5	Interviews 1 Group Interview/ Interview

The decision of joining similar individuals in the groups was taken based on the share of related interests, and experience of participants, as well as the possibility of connecting those people who have common patterns and experiences. In addition, the type of sampling used led to the formation of these groups. A snowball sampling technique was used for farmers. This type of sampling helped to identify stakeholders who are creating, transferring, and receiving knowledge and technology innovation towards or not sustainable actions. It was crucial to understand the interrelationship between formal and

informal learning and the changes that innovation brings to farming players. It was also important to explore whether their attitudes, values, and learning processes have changed for the conservation of natural resources as a result of these interactions. A varied representation of interests and viewpoints were considered. The intermediate farmers are members of Consejo Nacional de Productores de Chiles SC (National Producers Council Chiles Civil Society), and three of them are alumni of TIC. A non-random sample using a volunteer sampling technique was applied for alumni. The TIC helped in the identification of alumni who had applied technology innovation or knowledge in the agricultural sector. In particular, I targeted those alumni who had participated in agricultural technology innovation projects, genetic engineering research in agriculture, or those graduates managing agricultural technology-based companies to support farmers.

### **3.3.4 Strengths, Weaknesses, Opportunities, Threats (SWOT) Analysis**

A SWOT analysis is used to examine strengths, weaknesses, opportunities, and threats in their existing environment (Kaplan & Norton, 2008). This analysis can help institutions identify their issues and needs and to determine what strategies work and what strategies need to be changed (Rea & Kerzner, 1997). Strengths and weaknesses are regarded as internal factors, while opportunities and threats are external factors. Internal factors may be viewed as human capital, institutional structure, finance, manufacturing capabilities, and marketing. External factors may include macroeconomic circumstances, technological change, legislation, and socio-cultural changes (Kaplan & Norton, 2008). This analysis allowed insight into the examination of opportunities and barriers of local innovation system in the realm of sustainability. This tool also helped to identify the role of HEIs in sustainability and innovation activities.

A SWOT analysis was conducted to complement the data collected through interviews. Four previous interviewees were invited to participate in this analysis: the technological liaison chief, an alumnus, an external researcher of INIFAP (The National Institute of Forest and Agricultural Research), and the leader of habanero chile producers association, as indicated in Table 3-2. This decision was taken due to their preceding information given to the researcher and based on some preliminary results. A 150 minutes meeting was

conducted in two sections via a presentation. The role of every participant was to identify actions and activities that are important for the construction of a local innovation system, what the main barriers and opportunities are in building such system, as well as the strengths that support the product system in the region. Participants had the opportunity to discuss in depth issues through their own experiences and knowledge. Also, they mentioned problems they have faced within the product system. The four participants came from different working environments and educational backgrounds in order to enrich the information and look for alternatives and recommendations for this study, through an interactive and dynamic involvement.

Part 1: A presentation with a description of local innovation system considering the following aspects: key players, networks of collaboration, the diffusion of knowledge, as well as innovation contributing to sustainability initiatives. A SWOT analysis was run to examine innovation from a learning and collaborative approach for sustainability.

Part 2: The current development of innovative technology in the realm of sustainability in HEIs and their new role in local innovation systems. Ultimately the goal of this analysis was to aid in the provisions of suggestions for relevant and successful innovations in the realm of economic, social, and ecological sustainability.

### **3.4 Data Analysis**

Analysis of data was performed by transcribing conversations from individual and group interviews recordings, SWOT analysis, as well as by reviewing documents. Data collection and transcription were conducted in Spanish. Transcription of interviews was performed as soon as possible. As noted above, the interviews and SWOT data were collected in a face-to-face setting, this helped ensure as little loss of meaning from response/discussion to translation and coding. The setting of the interviews was varied according to the preference of each respondent. Some of them preferred to be interviewed in their offices, especially executives. Others preferred to talk while taking their lunch or coffee. Small farmers preferred to talk on their own plots. In a show of reciprocity for giving me their time and space in conversations, I offered them a small gift, a souvenir from Canada. In constructivist research it is critical to acknowledge the contribution of participants and it

was my hope that such souvenirs would be accepted as a token of my appreciation. While I present quotes from participants, these are not presented in Spanish. Instead I used my English translation to illustrate final comments and results. At the request of most participants this research will be translated into Spanish, where original quotes will be included to maintain the integrity of the information.

The SWOT analysis included the identification of words and common ideas that helped to discover the overall themes described below. The goal of the SWOT analysis was to obtain information from various sources, at the same time and location, that could be used to reach a common or different outcome/result as obtained in interviews and focus groups; it also assisted the researcher in recognizing relevant information for a better understanding of the problem and the creation of themes. Stakeholders participated and shared knowledge, listening to everyone's comments and contributing their own ideas and experiences. All participants had the same opportunities to express their views and knowledge. I participated as moderator in the SWOT and group meeting to facilitate the participants' expression of their opinions. I considered my role as one of a moderator: I did not make conclusions in advance, nor intervene or correct comments of participants. At the beginning of the session, I explained what the objective was, described some previous literature and results, and the basic rules of participation. I was an active promoter and listener in the interaction of participants with the aim of getting positively constructed responses. The relationship with them was cordial, informal, and respectful. I always showed trust and empathy to participants to facilitate the generation and exchange of ideas. For this activity, I rented a room with air conditioning and provided sandwiches, fruit, coffee, and tea. The room had a projector where participants could see all their input on the subject. The session was closed with a summary of the main points, giving opportunity to correct or add something else. As well, I thanked for their presence and participation with a small gift.

My role as a researcher was to learn from the diverse stakeholders; as such I read and analyzed the transcripts and documents. Data collection and analysis should be interactive and continue during the research process (Patton, 1990). In this sense, as I worked through the collection and analysis of the information I developed themes and meanings that helped



shape answers to my research questions. For instance, individual and group interviews, as well as SWOT and document analysis, helped me build a better understanding of the research purpose. Every interviewee was followed up with for clarification of terms and words, and more concrete details. In the case of SWOT analysis, the final presentation, including feedback and suggestions from participants, was sent by e-mail to verify the information provided and to incorporate data that were not considered in the meeting session. When I finished my field work, I continued with more in-depth data analysis. I analyzed the transcripts of interviews and SWOT analysis and I reviewed the selected documents in Spanish.

The information gathered at the meeting (SWOT analysis), interviews, and documents was imported into software for analysis and interpretation. I used a coding process to categorize data. Weitzman (2000) states that using software in research projects has some benefits, including writing, editing, coding, storage, content analysis, data display, and graphic mapping. However, he also mentions that no software will perform automatic analysis for the researcher. Software can help the research process, but this cannot substitute human ideas and intellectual efforts for conducting the research and analysis. The software was used to reduce the amount of time spent on organizing data and findings, and making use of diverse material. The data analysis process were supported and analyzed with the aid of qualitative text-analysis software NVivo 10 and Microsoft Word to categorize data and code theoretical categories of interviews and documents.

This software assists in the analysis of information and the generation of trends. The use of the NVivo facilitated the process of organizing and managing the extensive amount of data. It also supported easier search for specific text strings through all interviews and paragraphs. The interview transcripts were formatted in Microsoft Word to facilitate importing. The interview questions were assigned a group code when importing interviews into NVivo. Questions could then be displayed in the content panel in NVivo explorer. Moreover, important information related to the research objectives was divided by stakeholders and by paragraphs of every transcript. As a result, formatting of the interview transcripts helped to manage and analyze the data. However, linking and analyzing the

terms of sustainability with innovation for sustainability was complicated because the software did not bring up specific results related to this complicated topic. In this sense, the analysis of data was carried out manually by pen and paper for the reorganization and cross-identification of the responses by themes and categories. This manual procedure was important, to reflect on all crucial contributions for appropriate recommendations and future research.

Reading through the transcript allowed me to identify similar ideas, terms, and phrases, with the aim of determining categories and themes, as I said before. Based on the literature review and the inductive analysis of the data, I identified similar keywords and phrases that I categorized into six broad themes and sixteen sub-themes. The identified themes were related to the research objectives and questions developed for the study analysis. For this reason, it was important to create several key research components oriented to the development of interview questions, as indicated in table 3-3.

However, some components derived from diverse literature, especially those components proposed by Wieczorek and Hekkert (2012) and by Spielman and Birner (2008) helped me to identify relevant categories for this research. These authors created non-linear innovation system indicators including the role of key players, learning interactions, extension services, training, innovation networks, innovation outcomes, and openness to indigenous knowledge.

Table 3-3  
*Research Components*

Theory	Themes	Sub-themes	Interview Questions
Knowledge/ Learning Theory	Learning Interactions	The Creation of Interdisciplinary Groups. Knowledge and Learning Networks. The Integration of Scientific and Traditional Knowledge. Benefits and Problems.	How important is collaborating and learning on innovation activities with other regional or local players? What are some benefits of collaborative processes for the development and transfer of innovation? Have you considered the opportunity to collaborate and integrate scientific knowledge with traditional knowledge held by local farmers?
Innovation Systems	Local Innovation Systems	Level of association. Main actors. Product System.  Barriers and Opportunities.	What are those programs and mechanisms to promote innovation or agricultural innovation? What is a local innovation system?
	The role of HEIs	Knowledge Generation. Knowledge Transfer. Contribution to Sustainability.	What are some barriers for building innovation systems that promote or contribute to sustainability? What is the role of HEI should play inside innovation systems and sustainability innovation?
Sustainability System	Sustainability	Beliefs. Actions.	What does sustainability mean to you?
	Sustainability Perspectives	Society. Economy. Ecology.	What does sustainability innovation mean to you?
	Innovation for Sustainability	Technological/Non-technological innovation. Ethical and Social Order. Marketable Capacity.	How can local innovation systems improve living conditions, reduce poverty and consider the principles of sustainability?

Moreover, the proposed methodology highlights the importance of considering new analytical tools due to system linkages, interactions, and their complexity. These aspects and research objectives were also considered to design guide questions, coding schemes, and categories. Some indicators of sustainability were also considered as part of the research methods. Sustainability categories were based on a set of sustainable development indicators supporting a strong sustainability and agro ecological principles (OECD, 2008; Snapp & Pound, 2008), as well as participant responses. The above matrix describes in more detail the coded themes, sub-themes, and guide questions.

### **3.5 Reliability of the Research**

Rigor in qualitative research is established by meeting certain criteria to establish an acceptable level of reliability and validity. These criteria are dependability, credibility, and transferability (Hernández et al., 2010). One way I achieved dependability was collecting data with care and consistency. For example, all participants were only asked what was needed for the research, the link to the objectives of the study were made clear (as clear as possible), as well as the description of applied methods, coding procedures, categories, and themes were shared. Credibility was established by creating connections between data and evidence gathered through interviews, meetings, and documents. Triangulation of methods helped me complement the study and collect the information provided by participants. Furthermore, I was careful to provide opportunity for clarification and verification with participants; this helped ensure I was creating an accurate representation of the participants' knowledge, opinions, and beliefs. Therefore, I maintained ongoing contact via email to review with them the process of data collection and offer opportunities for follow up. But also, after every conversation and meeting, I made sure to provide a collection of information in case participants would want to add something later. Transferability in this study is directly related to the research goals: a contribution to knowledge on innovation for sustainability in the agricultural context. Transferability refers to research users determining the degree of similarity between one study and other studies and contexts (Hernández et al., 2010). This research provides the reader or user outcomes to evaluate the transferability by describing the setting, sector, the methods used, participants, and outcomes (themes and theory). It is unclear how broadly applied my research outcomes

might be, but it could provide guidelines and ideas for implementing alternatives and solutions in other environments and contexts. In this sense, innovation for sustainability through the integration of scientific and traditional knowledge may prove to be a field of knowledge that could be applied in various economic, social, and environmental sectors.

I realized during my conversations that as part of the research process and instrument, that my relationship and involvement with the participants was inherently a part of the research. In qualitative research the researcher should be adaptable, flexible, and respond to situations with tact and sympathy (Lincoln & Guba, 1985). For example, some intermediate farmers asked me to search for particular information in support of their product system, and two executives suggested that I enlarge or change my research in order to help them with other goals. I wondered: How to approach this circumstance without affecting our relationship and the integrity of my research process? This was a complex issue because I had to address these situations tactfully by explaining that when I return to México I may help in future research needs. Also, a small farmer invited me to participate in the rebuilding of cooperatives for local agricultural practice. Probably my experience regarding these issues may not be the best, but I recognized that there are opportunities and challenges concerning the increase of learning, skills, and practices when one person gets involved in social interactions.

### **3.6 Significance and Limitations**

The research study was conducted with the belief that innovation can contribute to sustainability not only in agriculture, but also in many other sectors. This is based on contributions that can be tested in diverse contexts. These contributions are: a) a conceptual approach on how sustainability principles can be inserted in innovation systems (technological or non-technological innovation); b) new public and institutional policies and programs supporting sustainability at all scales should be constructed and implemented; c) the opportunity of having a quintuple helix innovation model in local communities (the promotion of university-government-industry-civil society-natural environment), including traditional people because a new innovative dynamic can emerge that favors sustainable development; d) the identification of barriers and opportunities to

create innovation systems for sustainability; e) the benefits of both formal and informal learning interactions, as well as knowledge networks for the creation and renewal of innovations in the realm of sustainability. This situation implies that HEIs should play a new role on innovation and sustainability systems by strengthening the relationship with other local players. These statements affirm the contribution to knowledge and why this research is important to academia and policy making through its discussion regarding the inclusion of sustainability and multiple ways of knowing in innovation systems.

There were certain limitations concerning the interviewing technique for gathering information. Some stakeholders misunderstood questions, resulting in a reformulation and clarification of the question. Stakeholders representing institutions during interviews could present their personal perspectives which might not necessarily reflect the institution. Another limitation of the research was that not all key players could meet at the same time for focus groups due to both time and location. Two bureaucratic public institutions did not provide permission to conduct personal interviews. I expected to find in the Secretary of Agriculture, Livestock, Rural Development, Fisheries, and Feeding (SAGARPA) more information and policies related to the care and management of natural resources in agriculture, sustainable development, and its connection and interaction with farmers and other institutional players. I also expected to find in the Secretary of Economy what types of programs or funding are oriented to the agricultural sector, and its relationship with the desire of boosting the product system. This information would have been useful for the complementation of results.

An agro-industry located in the community did not accept a personal interview, and so open questions were sent by e-mail. I wanted to explore more about its responses, but I did not get a feedback. I found only a few small and Mayan farmers who plant the habanero chile in the Conkal community. There are other small farmers in the Conkal community, but they are not currently producing habanero chile. In fact, the horticulture activity in the community is decreasing. Since this situation may affect the research findings, I decided to change my strategy to applying in-depth individual interviews instead of conducting group interviews (similar to or synonymous with a focus group). This change of method allowed

me to collect personal interpretations and responses of those who share similar social and structural conditions. This change proved to be an enrichment, and as a researcher, I had the opportunity to learn and hear the voices of the local players. Their interpretations were well supported by the other sources of evidence and by equal participant opportunities to explore and express their perceptions and views. However, bringing together the small farmers would have generated different information, they would have had the opportunity to reaffirm and exchange their views, or they would have been able to listen what others would have said.

The initial design of the SWOT analysis had to be modified due to participant's time constraints and the complexity associated with inviting heterogeneous players with diverse points of view. I expected that two farmers and a researcher would be involved in this analysis, but when they noticed who other local players were, they chose not to participate because of disagreements they have had in the past. Perhaps these players have brought different perspectives on local innovation systems supporting sustainability. Bringing together such a diverse group to address an unexplored issue was fruitful, but it was difficult to manage at times because the respondents forgot to follow the basic rules of participation and communication. Moreover, the selection of documents was modified because when I was conducting my field work, I found more valuable documents related to research objectives.

Although I am Mexican, I speak Spanish and know the region; my main role was as an external observer. This could be a limitation in terms of my position as someone completely outside the region. I already knew of the product system (habanero chile), and some government efforts to position this product in the international market. But since that is not my field or area of expertise, it made it necessary to examine and learn about the various local player interactions within such a system, who the key players were, and what they were doing in terms of innovation and sustainability in agriculture. Probably if I had been involved in the product system as a biotechnologist, or as a social actor, my diagnosis and points of view would have been very different.

## CHAPTER FOUR

### RESEARCH FINDINGS

The main focus of this chapter is to present relevant findings encountered in the field study. I explored the terms of sustainability and innovation for sustainability as a frame of introduction and reference of this thesis. The multiple perspectives of stakeholders include a wide opinion on the forms and high complexity of agricultural development. Due to the diverse range of players involved in the production chain with different actions and beliefs, their way of engagement, and different styles in agricultural production, it was appropriated to address the views of those players to better integrate a vision of a local innovation system that may support sustainability in local and global scale. Building the results of the interviews, document analysis, and focus group led to the identification of themes provided by stakeholders' perspectives and experiences. The themes were categorized according to beliefs, actions, and the three dimensions of sustainability (social, ecological, and economic). The interrelation of these dimensions was considered as a useful guide to disaggregate perceptions of sustainability in agricultural context. The subsequent themes were classified according to frequently made comments in terms of local innovation system, the benefits of learning interactions, and the new role of HEIs.

#### **4.1 Understanding Sustainability and Innovation for Sustainability**

Examining multiple perspectives of sustainability and innovation provides a good appreciation of diverse worldviews. Points of view varied depending on each person's knowledge, beliefs, actions, interactions, and reality. The first section explores relationships among stakeholders' beliefs and actions on sustainability and the interrelation of the three dimensions of sustainability (social, ecological, and economic). Then, I illustrate the perceptions of participants on innovation for sustainability giving examples derived from interviews. The results of interviews provided stakeholder insights on sustainability and innovation for sustainability, which are analyzed throughout the first part of this chapter.



#### **4.1.1 Sustainability Perspectives**

Some important aspects of sustainability beliefs and actions in agriculture can be better understood through informal talks with stakeholders in their local context. Their local context is the workspace where they belong or where they are free to talk (an office, a crop, a coffee shop, or a lab). The local context, the degree of involvement in projects to improve production, level of education and experience, and the grade of participation in decision making processes concerning research, production, and development were observed. Amin and Cohendet (2004) suggest that people talking about their own environments and sharing personal information allows a better understanding of the problem and situation, and builds closer connections with others. In this sense, stakeholders could easily talk and describe what sustainability means for them. In spite of every participant having his own reality, it was interesting to note that they expressed similar opinions and beliefs about this term due mainly to similar experiences and information. Murphy (2011) suggest that cross-cultural perspectives can be related to empirical knowledge leading to knowledge based on experience, on good or bad, or on application. Thus, based on observations and first opinions, I classified sustainability beliefs and actions highlighting those differences and similarities obtained through interviews with stakeholders.

There were many similarities in sustainability beliefs among stakeholders. Respect for traditional knowledge and local culture was clear. An alumnus mentioned that he likes farming, and he has been working and learning from traditional farmers. He said: “these farmers have managed an agricultural system for many years; they have the knowledge and experience to share a better solution to today problems” (AL1). An intermediate farmer told me that traditional knowledge should be respected by modern farmers and society. “Hopefully we could create a synergy, but it is not an easy task” (F1). The second similarity is the preservation of biodiversity. Plants diversity and soil fertility help agro-ecosystems do not disappear. Agriculture and biodiversity are similar in terms of genetic diversity and long-term agricultural productivity. For most interviewed stakeholders this is the key to sustainability because most economic activities depend on the biodiversity conservation. A researcher pointed out that it is needed to preserve agro-ecosystems for a long period of time, paying attention mainly to soil fertility (R6). An alumnus said something similar

stating that soil fertility is the basis of farming, and farming depends on the preservation of nature (AL1). The main difference found in sustainability beliefs is the financial feasibility with the possibility of including social and ecological impacts. Most executives indicated that the economic and financial aspects are critical for producers' subsistence and local farming communities. These elements establish if a production, project, or program is sustainable or not.

Regarding sustainability actions it was interesting to note some practices that stakeholders are taking towards achieving sustainability. Learning from traditional farmers and sharing knowledge with others are part of the actions that alumni and researchers are undertaking to get more information concerning genetic resources. A researcher said that the institution is experimenting with new farming techniques, including sustainable crops where students along with researchers and some farmers are testing new methods. In the case of producers, the use of organic fertilizers and the use of plants and trees to control pests lead them to sustainable practices. For executives, there is a feeling that a fair income for producers should be part of sustainability. What is worth noting is that although there are differences and similarities, people are beginning to have an accurate understanding of sustainability. Table 4-1 illustrates a synopsis of these results. As well, it is worth mentioning that government actions and policies are not fully oriented to sustainability principles. Although, there is a law of sustainable rural development, this does not include policies and strategies to achieve sustainability as a whole system and considering the social, economic, and environmental principles. Multiple types of knowledge and different methods to practice agriculture are not considered in this law. In addition, sustainability is seen as part of the environmental goals and most actions and resources are allocated to solve ecological concerns. Thus, according to this analysis, the government has a good legislation on sustainable rural development, but it is not broadly well understood and lacks of applicability.

Table 4-1  
*The Beliefs and Actions of Sustainability*

Stakeholders	Sustainability Beliefs / Actions
Alumni	<i>Beliefs:</i> <ul style="list-style-type: none"> <li>- Respect for traditional knowledge.</li> <li>- Improving conditions of environment and society.</li> </ul> <i>Actions:</i> <ul style="list-style-type: none"> <li>- Sharing knowledge with small and intermediate producers.</li> </ul>
Researchers	<i>Beliefs:</i> <ul style="list-style-type: none"> <li>- Agro-systems that last longer than 200 or 300 years.</li> <li>- Little use of natural resources for analysis in labs.</li> <li>- Respect for local culture.</li> </ul> <i>Actions:</i> <ul style="list-style-type: none"> <li>- Learning from traditional people.</li> <li>- Experimenting with sustainable crops.</li> </ul>
Policy makers (Executives)	<i>Beliefs:</i> <ul style="list-style-type: none"> <li>- Financial Feasibility, with the possibility of including social and ecological impacts.</li> </ul> <i>Actions:</i> <ul style="list-style-type: none"> <li>- Maintaining a fair income for producers.</li> </ul>
Small farmers	<i>Beliefs:</i> <ul style="list-style-type: none"> <li>- Interest in preserving biodiversity.</li> <li>- Survival benefits.</li> </ul> <i>Actions:</i> <ul style="list-style-type: none"> <li>- Use of organic fertilizers.</li> <li>- Use of plants and trees to control pests.</li> </ul>
Intermediate farmers	<i>Beliefs:</i> <ul style="list-style-type: none"> <li>- Respect for traditional knowledge.</li> <li>- Interest in more healthy products.</li> <li>- Interest in preserving biodiversity.</li> </ul> <i>Actions:</i> <ul style="list-style-type: none"> <li>- Reduction of agrochemicals.</li> <li>- Use of organic fertilizers.</li> </ul>

The beliefs and actions analysis of sustainability served as a preamble to examine in more detail those aspects and comments that stakeholders identified as sustainability. Every region and community is different and unique; thus, it is crucial to know the interpretations of sustainability in this specific community. When I asked stakeholders the question, “what does sustainability mean?” it was not surprising to find during my interviews diverse

interpretations of sustainability. In fact, Mog (2004) says that defining sustainability can be difficult because it is highly contested (human values, perceptions, and interests). Although the descriptions varied somewhat, the general definition of sustainability for them is the interrelation of ecology, economy, and society as a sustainability system, meeting basic needs and living standards, financial security and stability, and the will to protect nature to ensure economic and non-economic wealth for all. Many of the themes identified during my interviews are related to the three dimensions of sustainability. Table 4-2 shows the term used, integrating them produced an interesting and unique sustainability concept. Thus, I will be presenting my data through social, economic, and ecological dimensions and some examples taken from interviews. Yet, before I present these data and examples, I illustrate two different examples to understand sustainability. In doing this, it is helped the importance of interconnecting the three dimensions of sustainability will be better understood.

The following two examples are related to farmers' experiences regarding sustainability. A Mayan farmer mentioned: "I do not understand the sustainability term, but what I understand is that we have to preserve the environment without affecting the land or causing erosion. If I sow habanero chile, I have to take care of the land using organic fertilizer such as the manure of sheep, turkeys, and chickens" (MF2). Another small farmer said that with few square meters you can feed the family and the remainder can be sold to the local community (SF). They are in favor of multiple crops or polyculture because these products can be consumed by the family and local community, and as a result they generate production diversity and self-sustainability. The purpose is to obtain social and economic benefits for producers and their families. Another Mayan farmer pointed out that he can expand if there were the certainty of production and a market to ensure fair incomes. However, this is impossible because there are many external factors and risks affecting crop production including climatic, credit, and market (MF1). Thus, small producers prefer to produce small plots and survive and preserve the soil fertility, rather than lose their crop and land. A small farmer explained his experience: "my production system is opencast, which needs certain agrochemicals to combat plagues, especially in habanero chile production. After the Gilberto hurricane pests and plant diseases appeared in the region; for

this reason, the use of agrochemicals is necessary. There are other traditional techniques and natural remedies that I am using such as planting fruit and neem trees and organic fertilizers during the harvest, but these are not enough for producing habanero chile at large scale” (MF2). In this way, the primary sector must be economically viable and social equity through a fair trade that improves the life of the farmers. This can be achieved by training and certification standards of small producers in their communities (Phills et al., 2008). However, these farmers cannot afford this kind of training because of the high costs. As a result of this situation, they cannot participate in a fair trade movement; they only aspire to produce at small scales.

Intermediate farmers indicated that sustainability is building a model that allows producers to be reliable suppliers 365 days a year. They can identify the problems, have alternatives and implement them. The result would be one model of sustainability, perhaps biased towards the economic dimension. This gives market security and certainty and system development at all stages. The economic benefits would flow from the primary sector, to secondary, and tertiary sectors. In other words, sustainability for them means recovering a farming investment. Nevertheless, more than 50% of intermediate farmers emphasized that sustainability is a system that can be functional and reliable over time; a system that can be maintained, useful, and friendly with the environment. In this sense, they are aware of the importance of providing safe and healthy products, and at the same time preserving biodiversity and traditional knowledge in agriculture. For example, they are trying to reduce the use of agrochemicals not only to follow international regulations, but also to maintain human health, ecological strength, and cultural diversity. Thus, they are increasing their environmental awareness, but at the same time obtaining economic return by meeting international standards. This situation meets an agricultural system requirement of being productive and profitable, whether or not production is organic (Snapp & Pound, 2008). Unlike small farmers, they have the financial and educational capacity to face certification processes that allow them to participate in fair trades.

These two examples involve different realities and experiences to define and understand sustainability. It is remarkable to note how sustainability is seen through different lenses

and situations. Through the narratives of these farmer stakeholders I could realize why environmental and economic aspects are important elements of sustainability. One narrative shows a simple way to see sustainability as the capacity to generate social and natural wealth while continuing production. Another considers sustainability as a financial model, including markets and investments, but considering the environment. The former is considered strong sustainability, whereas the latter is weak sustainability. Whether the economy or ecology should be considered, the most relevant fact is that the economic and social dimensions rely on the environmental dimension because farming production comes from natural capital (Daly, 2004). In this way, these dimensions (social, ecological, and economic) should be interrelated to understand sustainability. This holistic perspective is supported by diverse authors (Baker et al., 1997; Daly, 2004; Dresner, 2008). This interrelation is explained in more detail by describing every element.

#### **4.1.1.1 Social Sustainability**

Quality of life was one of the aspects where more stakeholders felt similarly. More than 50% of all stakeholders mentioned that improving the social and environmental conditions of farmers and society should be important to achieving sustainability. According to these stakeholders, quality of life represents self-sufficiency, healthy and sufficient food, and respect for traditional knowledge and cultural diversity. According to the World Bank (2010a) reports that quality of life represents economic and human development, but also social and ecological justice. In this sense, quality of life for farming communities means preserving their traditions, respecting the integration of their knowledge, care for and preserving the land which supports farming, and having plots that enable them to improve their economic conditions.

Three examples illustrate this point. From an alumnus “sustainability is an activity that involves health. In this sense, we should not produce sustainably thinking only of what we sell, we have to improve production processes because it is what we eat, allowing us to reach better quality of life” (AL3). Thus, every farming family should be sustained by their parcel through the improved production including healthy land and food. A researcher said that “ecological, economic, and social welfare is associated with reaching quality of life through how humans behave, act, and make decisions” (R6). For example, an alumnus

manages a family crop along with his father. Although he has scientific knowledge, he always listens to his father's recommendations because these are usually assertive. Hence, respecting others' comments and suggestions considers all options towards quality of life for all. Another researcher mentioned that "sustainability means achieving the ultimate in quality and performance while helping to create a social and ecological balance" (R5). In this sense, the ability to maintain a social, economic, and ecological balance would be synonymous with quality of life. These examples have four characteristics: health, behavior, inclusiveness, and welfare. Thus, by attending to the method of production, how we relate with others, behave, and make decisions related to the environment, we will have healthy products and improved quality of life.

Resilient communities were another aspect mentioned by approximately 40% of all stakeholders. The term "resilience" as part of sustainability emerged in one executive response. This executive stated that he learned this term during a United Nations meeting. He emphasized: "sustainability is synonymous with the term resilience, which is the ability of an ecosystem, when a factor is altered, to be recovered and reach a degree of balance; although this ecosystem is not necessarily identical to the original. For example, the resilience and sustainability of the current Mayan people is totally different from the prehispanic Mayan people 300 years ago, because the environmental and social conditions are not the same" (EX4). As I mentioned above, after the Gilberto hurricane farmers had to adapt to new situations by trying to recover the balance of their agro-system. Every climatologically or technologically influence means system adaptation and transformation for many producers. Vanloqueren and Baret (2009) indicate that agricultural resilience is a reaction to disturbances; for this reason, soil quality and nutrition is an important factor creating such agricultural resilience. An alumnus indicated that he focuses on issues of biological control and reduction of herbicides, and soil improvement; for this reason, he understands what producers were doing for planting, how they have been planting, and how they have had to adapt to new circumstances (AL1). For many years they have harvested the forest and planted, but they lose soil fertility. Now, they are improving soil fertility due to the acceptance of new information and new practices, so they can continue planting in their own plots without deforestation. He believes that there has been an adaptation and transformation among producers concerning the farming resilience in terms of biological

control and soil fertility. In this sense, resilience in farming is related to change and the capacity to adapt and transform to new situations.

#### **4.1.1.2 Environmental Sustainability**

Although, there were different opinions about sustainability, all stakeholders agreed that sustainability is related to the conservation of natural ecosystems. This response is similar to that given by Pearce, et al. (1989) who stated that maintaining natural capital can support economic systems. In this sense, the protection of nature is a theme identified by all stakeholders as crucial for sustainability. Almost 90% of interviewees described this aspect of sustainability as respecting the environment and the coexistence of nature and humans. Most researchers described it as the rational use of natural resources without causing a negative impact on ecosystems. Some alumni indicated such environmental concerns as avoiding harm to nature and contaminating water and groundwater (AL4, 5, 2). For example, an executive told that “the rational and appropriate use of the environmental elements such as water, soil, and vegetation is sustainability” (EX2). A researcher said that sustainability should recognize the strategic smart growth of human activities while minimizing impact on the environment (R9). Similarly, an alumnus mentioned that “human activities should not jeopardize the environment and contaminate water and soil; it is about promoting environmental care” (AL1). These descriptions have in common the human right to protect the environment and ecosystem. For this reason, some researchers concluded that it is important to create strategies to maximize benefits from nature, while at the same time ensuring nature is not negatively affected by human activities (R6, 9, 7). For executives, the importance of using natural resources appropriately and practicing new and better ways of farming should be recognized. The comment of another executive was: “it is to protect the environment and ecosystems by reducing the use of toxic products” (EX1). A new way to maintain or increase biodiversity may be the planting of multiple crops that are a combination of vegetables, fruit, and timber trees to combat deforestation, as one executive stated (EX5). If we do not conserve our natural resources, humans will lose the ability to produce and survive in the long term.

Long term survival was another aspect that approximately 45% of all stakeholders mentioned regarding sustainability. This term refers to a better use of natural resources



without affecting the ecological balance, having long term agro ecosystems, and ensuring the human survival. WFEO (2002) indicates that in the food cycle, humans should consider diverse natural processes and connected structures in order to continue with this cycle for long time. For instance, a researcher said that “the use of a natural residue to support ecosystem survival should be considered when taking samples from nature” (R6). Similarly, another researcher pointed out that “it is something that endures through time and space, it is sustainable because it does not deteriorate ecological and human conditions. For illustration, a crop should be used rationally and kindly with regard to the environment and humans” (R9). An executive and a researcher agreed: it is a process that can be maintained for a long time and by natural cycles. Thus, soil fertility should be taken into consideration for preserving agro systems with high productivity with a view 200 or 300 years into the future (EX1, R9). Long term survival should involve a balance between the use of natural resources for production and consumption and the time it takes to recover that natural element. It is about limiting excessive and intensive farming to preserve local environments (Norberg-Hodge et al., 2002). Thus, long term survival for agriculture is the coexistence capacity of humans with nature to ensure farming production over a long period of time.

#### **4.1.1.3 Economic Sustainability**

Quality of production and return on investment were considered by most stakeholders due to the relationship between economic activities and ecological conservation. Alumni working on research and development agreed that sustainability is related to the market through the fulfillment of quality standards and production capacity (AL4, 5). If producers do not fulfill these requirements, they cannot compete with other national or imported products because of production quality and capacity. Similarly, an alumnus working as a consultant mentioned that thinking of sustainability should not only consider production for markets, but also for self-consumption (AL1). This means that farmers have to satisfy national and international norms and standards, but also produce healthy products for their own consumption. As it was observed before, the problem with this situation is access to technical training and financial resources, especially for small farmers trying to meet those quality requirements, as well as the soil improvement and biological control. For instance,

the use of organic matter provides healthy and more resistant plants to reach the goal of improving soil fertility. Two alumni agreed that there will be more sustainable farming in the next five or ten years, but that presently it was less than ideal (AL1, 3). To this point, an intermediate farmer indicated that “This year the US FDA put out a new regulation on the use of agrochemicals, and it is not allowing the use of many of them because the damage they are causing to the environment, plants, and humans. While we are getting closer to reliably producing organic products, the handling of such products is very complex and the habanero chile has no explicit organic description. It would be good that producers can use both of them, within the allowable range, to offer your family and abroad market safe and healthy products” (F1). For this reason, Snapp and Pound (2008) state that agro-ecology and sustainability in agriculture should be viable as long as the consideration of biodiversity, pest control, healthy crops, recycled nutrient resources and energy, and types of inputs are being taken. In addition, agro-ecology should be supported by more incentives and policies at all scales to motivate new modes of production (Vanloqueren & Baret, 2009). Nevertheless, this is not happening because in America most powerful corporations for agriculture have made the rules and policies that governments have supported through trade agreements and by participating in neoliberal economic system. For this reason, subsidizing farmers with agrochemicals for maximizing production is an incentive way to continue using them.

More than 50% of executives, an alumnus, and intermediate farmers stated that financial feasibility should be the basis of sustainability, i.e. return on investment. “If a project is not technically and financially feasible, then it is not sustainable” (EX3). A product system is sustainable when there is the possibility of having extra money to reinvest in production and get the product to the market. This production must afford all associated costs, receive a fair market price, and grow over time, another executive suggested (EX6). Executives from industry and some public institutions, and intermediate farmers tended to define sustainability in terms of monetary return and investment. In this sense, any project or initiative should include economic benefits with the possibility of integrating social and ecological effects. For instance, sustainability in agriculture means that every farmer should have enough financial resources and inputs to continue planting and avoid abandoning their

land. If the cost and the type of inputs, as well as the access to local knowledge and local seed systems are not considered, then, sustainability goals in agriculture will not be reached (Snapp & Pound, 2008). In this sense, better practices in agriculture should bring economic benefits as well as environmental awareness (Gliessman & Rosemeyer, 2010). An alumnus commented that “he can observe better performance in terms of kilograms per acre when integrated pest management is used. The greatest benefits are when reducing the use of agrochemicals in the cultivation and all possible strategies for pest control are put into practice. These two trends can be profitable and survive over time, because without profitability, producers risk abandoning their land and no longer running an agro-business. Only those producers, who have their cultivation as subsistence and as their only option, will survive. For this reason, we, as farming consultants, must seek to generate returns in order to contribute to the development of agricultural communities” (AL3).

In conclusion, for the majority of stakeholders the social dimension of sustainability represents respect for local culture and knowledge, improving the quality of production and quality of life, sufficient and healthy food, and long-term survival. Concerning the economic dimension, alumni and executives said that farming systems are measured in terms of production capacity, financial viability, and market allocation. As well, intermediate producers assumed return on investment is a necessary element of a sustainable agro-system. Most stakeholders expressed the importance of respecting the environment and the coexistence between humans and nature, as well as using natural resources rationally. Moreover, farmers stated the importance of reducing agrochemicals and increasing polyculture as part of ensuring ecological integrity. Results span the breadth of sustainability in farming communities; this seems logical given quality of life in farming includes aspects as part of society, financial stability as part of economy, and biodiversity preservation as part of ecology, as illustrated in table 4-2.

Table 4-2  
*Summary of Sustainability Perspectives*

Society (farming communities)	Economy (financial stability of a farming system)	Ecology (biological preservation)
Sustainable model in terms of return of investment, and An activity that allows long-term survival		
Improve the quality of production and the quality of life of people by protecting nature		

These categories overlap because sustainability seeks economic development through monetary return and investment, while simultaneously seeking social and environmental development by building relationships of respect, increasing areas of knowledge, and awareness and protection of the environment. Sustainability should then be seen as the crossing of the social, economic, and ecological domains. Synthesizing these domains I could observe a new approach to understand sustainability through two general particularities: a) sustainable model in terms of return of investment that is related to an activity that allows long-term survival, and b) improve the quality of production and the quality of life of people by protecting nature. These two particularities represent sustainability as a whole system, and the opportunity to write the voice of diverse stakeholders when they defined the term ‘sustainability’ according to their farming activities. This seems to indicate that sustainability should include these three dimensions (social, ecological, and economic), and symbolizes an approach of why diverse players should be involved in defining clearly this term in their farming system and local community with the idea to better impact locally and globally.

#### **4.1.2 Innovation for Sustainability**

Innovation for sustainability was seen by most stakeholders as the introduction of new knowledge and ideas to improve production systems that do not harm the environment, as well as the generation of technology applied to farming with the aim of preserving nature and increasing food production. In a complex and interesting way this is connected to and overlaps with sustainability in three ways: a) the rational and proper use of environmental elements such as water, soil, vegetation, and climate that would support society into the future, b) financial capital to reinvest in production and generate food, c) the improvement of the quality of production and the protection of the environment. If knowledge is a relevant component of innovation, then this can contribute to sustainability through the reduction of ecological risk and pollution. Indeed, Karakosta et al. (2010) argue that the generation of knowledge is important for economic innovation, but innovation also needs to boost the improvement of society and ecology.

For executives and intermediate farmers innovation for sustainability is the marketable capacity of new products and ideas. This is based on a basic definition of innovation: the development and commercialization of goods and services into the market (Phillips, 2007). However, some researchers stated that the development of improved seeds should be considered innovative action that contributes to sustainability. In this regard, Carayannis and Ziemnowicz (2007) say that innovation can occur individually, or inside knowledge networks, because members are learning and using their creativity. The ethical aspect was considered by small farmers as the basis of innovation when a product is ready for sale. This comment is similar to what Woodhouse (2011) said about the civil commons, which involve human responsibilities with all living beings, and the well-being of all people. When a new product is going to the market, it should have been produced with regard for quality control and ethical standards. Additionally, researchers suggested the importance of considering the needs of rural producers as a social justice issue. Seyfang and Smith (2007) indicate that civil society plays an important role in creating and generating new ideas for transforming production. Thus, rural producers can express their ideas and needs in order to change the course of research and the production processes. Here, I analyze three identified

characteristics of innovation for sustainability: a) generation of new procedures, technology, and methods, b) the marketable capacity of new products, and c) the ethical and social order of the products that are offered to a segment of the market.

Generation of new procedures, technology, and methods refers to new techniques and ideas for production processes. For instance, most alumni said that innovation for sustainability is the introduction of new alternatives for production by making things differently including the application of knowledge, and stop the exploitation of natural resources allowing the survival of agro-ecosystems. An alumnus emphasized that “if we do not innovate, not only will we have poor quality of life, but also we will not survive in the future” (AL1). This suggests the need to change current production systems, while also considering environmental protection and the well-being of society are all equally important. Similarly, another alumnus stated that changing current production systems may not require advanced technology, but might include adopting more natural approaches, such as organic products (AL2). Some researchers pointed out that the development of new processes and more efficient procedures by reducing environmental impact (water, air, and biodiversity) and acknowledging long-term benefits would be innovating for sustainability. For example, having more tolerant, yield worthy, and better varieties of plants adapted to climate, pests, and diseases will support economic and ecological sustainability (R7, 4). As a result, the use of fewer agrochemicals or not using them would be one goal towards healthier crops and an improved environment. A researcher stressed “if you are going to utilize the leaves of a plant to analyze substrate, you have to see what method is better because not all methods have the same outcomes. Hence, it is necessary to try new methods or different ideas to obtain a prototype and measure the result” (R6).

Marketable capacity was mentioned by the majority of executives and intermediate farmers. They defined innovation as including improved processes, ideas, or products that can be successfully taken to the market. For instance, if a new variety of seed is created, tested, and used by producers, this is an innovation. Innovation means the adoption of technology already tested and ready to be transferred and implemented. Two executives mentioned that innovation allows a producer to obtain products that can achieve success in the global

market (EX4, 3). There were some contrary suggestions as well, such an innovation resulting in the creation of seed varieties that might not make it to market, as I mentioned before. Thus, any individual at any scale can innovate, learn, and transmit an idea inside a system to improve processes, strategies, or living conditions (Dorf, 2001). An executive said that “many institutions are creating innovation but not for sustainability. It is economically profitable, but not sustainable. Thus, it is important to link one with the other, but not necessary to fulfill this link in all instances” (EX1). Similarly, another executive stressed that the application of an innovation for sustainability is obviously having enough information that allows the creation of sustainable production that lasts. There is good technology for sustainability, but it has not been implemented because somehow the conditions are not given for its application (EX5). Others stakeholders commented that it is good to improve processes, services, and products that reach the market, but also enable the survival of the society over time. The goal is for producers to sell their products and have money, but also they need to ensure continuous production. For example, an intermediate farmer indicated that “innovation for sustainability is the application of techniques and technology know-how regarding measurement, production, and maximizing plant yield through the application of innovation” (F2). This farmer emphasized that applying farming practices and knowledge to maximize crop yield and reduce pollution may help farmers have functional and sustainable agro systems. In addition, some executives concluded that certain political and market conditions are necessary to set innovation targets for sustainability. Something similar was said by Kemp et al. (2005): a broad range of changes needs to happen, including infrastructure, institutional, and social changes.

Ethical and social order was an aspect that some researchers and small farmers considered as innovation that would contribute to sustainability. Researchers indicated that innovation activity should consider the needs and problems of rural actors and producers. In this sense, if sustainability for researchers is the preservation of agro systems for many years through the adequate use of natural resources and the environment, the link with innovation would be to address social and/or ecological need. A good example was given by a researcher “any innovation that is being addressed today has to take into consideration rural actors. Innovation must go according to their needs. An abrupt innovation may mean that they will

not to implement. We should slowly change the mindset of producers and train them for the medium and long term. Libraries are full of research that does not reach where it is needed, so it is important to integrate producers into the research process” (R7). The rapprochement with other stakeholders would be achieved by generating innovation and knowledge focused on solving a current problem. In fact, many researchers are working with some producers on the improvement of plant varieties and products including organic inputs as part of innovative research (R6). Thus, the innovative actions of researchers can be attributed to sustainability through the testing of new methods and procedures in farming crops. Another researcher said that “scientific work should be conducted with the approach of generating producer benefit and consumer welfare; this should be fundamental” (R3). Small farmers struggled to respond to this question (about innovation); however, they said that it is about technique and the ethical order of the product that is going to be offered to the market. A small farmer told “this is a new practice that a producer will apply to the production process, and during this process, he will apply his ethics and knowledge thinking of a social and ethical order, before thinking in an economic order, because it is needed to think about the society that will consume such product” (SF1). The major findings regarding innovation for sustainability are summed in table 4-3 by stakeholder.

Innovation for sustainability was understood by most stakeholders to be the creation and the improvement of processes or products that simultaneously support sustainability. Executives understood this concept as a new product in the market and improved technology to ensure present and future farming production. For small farmers and researchers innovation for sustainability was related to farming practice, dealing with uncertainty, and the consideration of both ethical and social order. In this sense, researchers suggested that innovation should target social and ecological needs, as well as attend the problems of rural producers. Small farmers, alumni, and researchers agreed with the suggestion of developing new methods and products that are environmentally friendly and satisfy consumers.



Table 4-3  
*The Understanding of Innovation for Sustainability*

Stakeholders	Innovation for Sustainability
Alumni (7)	<ul style="list-style-type: none"> <li>- A shift in the production systems.</li> <li>- The generation of new technology for the production of healthy and organic products.</li> <li>- It is the application of knowledge for surviving by understanding that it is not exploitation, but protection of natural resources.</li> </ul>
Researchers (10)	<ul style="list-style-type: none"> <li>- The generation and improved seed varieties, and products.</li> <li>- The development of new procedures that have less impact on the environment.</li> <li>- Innovation should be in accordance to the needs and acceptance of rural producers.</li> </ul>
Policy makers (Executives) (11)	<ul style="list-style-type: none"> <li>- Marketable capacity of new ideas and products.</li> <li>- A crop based on higher technology capable to distribute the product, but also ensure continuous cropping.</li> </ul>
Small farmers (3)	<ul style="list-style-type: none"> <li>- Ethical and social order of what is going to offer to society.</li> <li>- The creation of productive diversity for the community consumption.</li> <li>- Technique and deal with uncertainty.</li> </ul>
Intermediate farmers (5)	<ul style="list-style-type: none"> <li>- Marketable capacity of new ideas and products.</li> <li>- The generation of new technology and methods for a better quality production of healthy and organic products.</li> </ul>

Therefore, I could incorporate innovation supporting sustainability in three broad views: a) reduction of agrochemicals and rational use of natural resources, b) increase polyculture and healthy products, and c) a sustainable and functional agro-ecosystem preserving natural elements. All of which are consistent with what Gliessman and Rosemeyer (2010) said about producers moving to better practices considering economic benefits, environmental conditions, and social improvements in agricultural sector for long time. Thus, in the context of farming, innovation will not resolve all problems, but it should play an important role in reaching commercial efficiency (economic sustainability), health and human well-being (social sustainability), and the non-decrease of natural environment (ecological sustainability), through the generation of new knowledge and the improvement of processes and products.

## 4.2 Local Innovation System

The Mexican national innovation system is composed of major players, such as universities, public research center, government institutions, a small number of strong enterprises, and a few financial institutions. The government is the main regulatory agency within this system and defines and transforms policies and instruments to support and promote science, technology, and innovation. México is not considered to have a well-articulated innovation system. Efforts have been undertaken to strengthen university-government-industry relationship, especially in provinces with higher scientific and technological development such in the north of the country. However, this approach is in its infancy in the south of the country. HEIs have had success internationally, and have signed agreements of collaboration with state and federal governments outside México. For instance, Casas et al. (2000) recognized spaces of knowledge in the Bajío region that represent successful implementation of the triple helix model of innovation. This region is starting to build institutional interactions for collaboration and learning. The Mexican Council for sustainable rural development requires that agencies and bodies representing the various actors and stakeholders of rural communities be responsible for the promotion of organizations and other agents associated with the primary sector. This serves as the foundation for decentralized action on planning, monitoring, updating, and evaluation of agricultural development programs and sustainable rural development. As well, this Mexican council establishes through consultation with the departments and agencies of the public and private and social sector the institutional capacity to integrate national research and technology transfer for rural development. The Mexican Council promotes agricultural research, technological development, technological appropriation and validation, and technology transfer to producers, inducing sustainable practices and improved seed production, including natives crops; the development of human resources, technical assistance and capacity of the economic and social agents of rural society; and public and private investment to expand and improve infrastructure. For this reason, this council is associated with the Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA) and Fundación Produce to drive inter-institutional and multidisciplinary megaprojects for agriculture. SAGARPA is a governmental agency that manages

agricultural programs and funded research. Fundación Produce is a NGO that manages private and public funds targeted to the development of agricultural technology and innovation. As a result, diverse final products and prototypes are generated by research centers and universities, which support the technological development of product systems. The CONACYT through innovation programs and projects funds also supports research, development, and transfer of technology, including the agricultural sector. In this sense, CONACYT invites researchers, students, businesses, and other economic agents to link together for the generation of scientific and technological projects aimed primarily at increasing regional economic development. While the council reported that programs focused on sustainability are scarce, some local actors are starting to contribute to the environmental and social improvement of agricultural communities. For example, in the community of Mani, an education center based on agro-ecology seeks to reconsider traditions, cultural customs, and rural ethics through the boost of sustainability. This educative center trains Mayan farmers and woman who want to pursue agro-ecology practice as a mean of respecting the environment and increase their social and economic capacities (CONCYTEY, 2009).

As I mentioned at the beginning of the chapter, Yucatán attempted to establish a production chain model based on a triple helix. However, this model has not been consolidated; it is only at an incipient stage. Some agreements have been established among various public institutions and companies to leverage infrastructure, educational, and technological capacities in order to boost product systems in the primary sector. For this reason, the technological innovation agenda of Yucatán 2011 emphasized the importance of improving the productivity of habanero chile and encouraging the production of primary sector technologies with fewer pollutants to favor crop competitiveness at both national and international levels. As a result, two innovation hubs were contemplated for Yucatán: the development of (1) social impact studies and (2) strategies for technology transfer. A special program of science, technology, and innovation 2008-2012 encouraged the development of technological innovation for the application of technology focusing on sustainable development. The purpose of the program was to link the various sectors of society to boost environmental care, encourage multidisciplinary participation in research,

and promote the skills and learning of participants. Despite many efforts that some top-down players from Yucatán have made to create a strong innovation system (i.e. triple helix model) for the habanero chile, this system has not yet matured. However, it is important to emphasize the benefits and opportunities that the region has to build such local innovation systems. Through networks of knowledge and learning and the integration of bottom-up local players, as an essential part of the system, these can support a local and rural community socially, economically, and ecologically. Thus, building relationships, strong structures, social rules, and adequate policies may guide to the foundation of quintuple helix model in the region, particularly in the habanero chile product system.

In this way and considering the above background, this section addresses my second research objective: identify the opportunities and barriers in building local innovation systems through the exploration of how those players are learning to learn, interact, generate, and transfer knowledge. To meet this objective three methods were used: interviews, document and SWOT analysis. Before the identification of those opportunities and barriers, I asked participants about local innovation systems. The interpretations of the term *local innovation system* allowed a better understanding before exploring how stakeholders in this system learn, change, and innovate. For most stakeholders there was not clear definition of local innovation system. In fact, little attention has been given to this term, which does not have a clear definition. Some authors have defined national and regional innovation systems, but not local innovation systems. Other authors refer to local innovation systems as the interaction of different innovation agents (including traditional people), formal and informal structures, and functions inserted in local communities (Torri & Laplante, 2009). However, there were some ideas expressed by interviewees regarding local innovation systems. I wanted to explore more how local innovation systems can improve living conditions, reduce poverty, and consider the principles of sustainability through the interviews. Thus, I also present some comments and examples regarding this question.

An intermediate producer said that “this system is the creation of a cluster, which means a collection of corporations that are simultaneously providers and suppliers, ranging from the

primary sector to the target market” (F1). Another intermediate producer pointed out that local innovation systems already exist. Maybe these are not consolidated, but there are public and private institutions participating to make this possible. Similarly, an alumnus indicated that there are local communities that generate and transfer knowledge, but it is still an incipient system (AL4). Another alumnus commented that this system is in farming communities, where farmers are the main actors (AL3). A researcher pointed out that “it is a dynamic system, which is managed by the producers because they adapt to environmental conditions through their creativity, experience, and knowledge” (R1). To this regard, an innovation system can occur in a social context such as small farmers, which involves learning interactions and connectivity (Tapsell & Woods, 2008). One of the executives emphasized that the concept should be narrower, i.e. “a system of agricultural innovation, where the key actors meet to achieve objectives, attain greater productivity, and greater impact” (EX4). Another executive said that a local innovation system is where a technology or better practices are promoted for the improvement of production (EX3). For another executive, a local innovation system means having the most advanced knowledge. It is the most important value in the world; a country grows and moves faster based on knowledge generation, innovation, and technology (EX2). Another researcher said: “I do not understand innovation systems as entities per se, but as actions or activities that should be applied to all productive chains” (R6). These responses suggest a potential disconnection between market focused actors (executives and intermediate farmers) and environmental/local/traditional actors (small-hold farmers and to a lesser extent, researchers).

Interviewees who participated in the SWOT analysis defined a local innovation system as “an interaction between all links of the production system; generate innovations to be an efficient and dynamic system to all levels (education, industrialization, commercialization, technical assistance, primary production).” They concluded that a local innovation system is a system in which local capacities (infrastructure and intellectual capital) is used. This local capacity includes not only the academic element, but also the production infrastructure, business, and non-business activities. These last activities should integrate rural groups that are organized to carry out self-sustaining activities, provisions for

communities, and may also have a commercial component. In general, less than 40% of stakeholders indicated that local innovation systems are focused on a particular sector and products connecting public and private organizations in learning and the exploration of sustainability actions. Some executives and intermediate farmers pointed out that this system needs to be strengthened and linked in terms of innovation contributing to sustainability. Three main elements of a local innovation system were identified based on stakeholder interpretations. These include partnership level, main actors, and the production system, as illustrated in table 4-4 without an order of importance.

Table 4-4  
*Three Elements of a Local Innovation System*

Partnership level	<ul style="list-style-type: none"> <li>- Generation and exchange of knowledge and techniques.</li> <li>- The researcher carries information to communities.</li> <li>- Promotion of technology for best practices.</li> <li>- One technology is transferred and adopted by a group of producers, and these in turn transmit it to another group of producers. Then, there is a chain of knowledge transmission.</li> <li>- Use of local capacities including intellectual and physical capital for the development and application of innovative technology.</li> <li>- Training to improve production systems.</li> </ul>
Main actors	<ul style="list-style-type: none"> <li>- Producers.</li> <li>- Institutions of Higher Education.</li> <li>- Research Centre.</li> <li>- Rural associations.</li> <li>- Industries.</li> <li>- NGO.</li> </ul>
Production system	<ul style="list-style-type: none"> <li>- This system is embedded in a community to work aspects related to the management of natural resources and environmental conditions.</li> <li>- The improvement of crop process and the product.</li> <li>- System based on the value of knowledge system, which generates economic and social welfare.</li> <li>- Response to local needs and a supply chain.</li> </ul>

When I asked how local innovation systems can improve living conditions, reduce poverty, and consider the principles of sustainability, interesting insights were collected. In general, results indicated that learning interactions and the generation and transfer of knowledge can support the social, ecological, and economic improvement of local communities. 60% of stakeholders indicated that they had no idea if local innovation systems already exist in the

province, and how these may contribute to the quality of life and sustainability. Indeed, a researcher mentioned: “I cannot speak of a system of innovation that impacts the quality of life or that impacts directly on farming communities, I ignore this situation” (R4). Below, there are some additional comments and examples.

An executive said: “I do not know if this system exists, but it is definitely not paying off, as the supply chain is not properly coordinated, each link in the supply chain fails, especially the primary sector. We can have the best men of science, innovation, and good services, but we are still having extreme poverty among our chile producers. What is needed is articulation of a system oriented to sustainability principles” (EX1). A researcher commented that an interaction among local stakeholders is not completely integrated because each institution works individually/independently. There is no interaction or teamwork toward common goals. If this system existed it could increase living standards and reduce poverty and pollution as well as troubleshoot the farming through the combination of knowledge (R9). These responses are very similar to those found in a research conducted by Carlsson et al., (2002) stressing that it is difficult to describe a system’s performance and relevant actors due to the complexity in the system. Hence, institutional arrangements, regulations, and clear policies are needed in a system because many of its elements are co-evolving. Another executive stated that the producer is not being considered. The industries set the market price. Therefore, producers are always working at loss; otherwise they lose 100% of their crop (EX5). So, a system does not exist in which the producer is taken into consideration as a person with meaningful risks. This executive added that all players at all scales and spaces should look below themselves, look to the places where the food is produced, and look how producers are living (EX5). Conversely, two executives said: a local innovation system exists in and alongside research centers that are constantly generating knowledge, innovation and technology for different sectors. In fact, some research on a species of octopus, which was patented, was sold to another country. That generates a lot of economic development and social welfare. So behind each research team or project, knowledge, and development, many jobs can be generated and new opportunity can be had (EX2, 3). In this sense, another researcher mentioned that an innovation system cannot function if there are not guidelines. A structure is needed in which technology is applied specifically to governmental development

programs (R5). This means that governments could use that knowledge and technology generated in research institutions to solve social and environmental problems in communities and regions of strategic importance. Describing a local innovation system is not difficult, but recognizing its existence and if it is supporting sustainability principles is contradictory and difficult to assume. A system is a complex set of interrelated elements, where human beliefs, rules, and traditions are involved (Clayton & Radcliffe, 1997). It is not easy to determine what element or change is having a positive or negative impact on the system. However, it is clear that public programs and policies, global market standards, and the lack of local alliances are not working well towards building local innovation systems that achieve sustainability goals. Hence, an innovation system has to be adapted to the local setting. Some processes, the introduction of any technology, and learning for adaptation can be changed, including introducing players at different scales. Currently, it appears that the articulated conditions for building a quintuple helix model in the region are not present, but the opportunity may lie on how multiple local players can learn to learn, interact, and change in the present and future.

### **4.3 Learning Interactions**

According to interviewees, the benefits of collaborating and interacting include the sharing and the diffusion of knowledge through social groups and networks. This experience stresses the importance of learning by interacting through triple loop learning because it implies a dynamic participation among players and system orientation to encourage transformation and change (Armitage et al., 2008). For instance, most researchers pointed out that interaction and collaboration make a system stronger; the design and results of the projects are better. The vision of many people is very different from a single vision because methods and strategies can be managed more efficiently. A similar comment by a researcher was “collaborating with other players and researchers shortens the time spent on research, and shared learning and infrastructure would make us stronger as a system” (R7). In the same way, an executive reported that the purpose of collaborating is not wasting institutional efforts (EX4). In this sense, the role of government might be to combine the contributions that industries, institutions, and producers are making by providing training, resources, and outcome assessment. Conversely, two executives reported that working with



various institutions that view farming as a learning system is necessary. For example, multiple outputs might be generated by a single product (powder, dehydrated, hybrid seeds), which can be promoted in the market. This can be achieved by bringing together different farming players to improve the development of agribusiness. As a result, if agribusiness diversifies and commercializes sub-products from a single product, this could increase producer income (EX7, 2). However, small farmers (local and traditional) in the region are generally not involved in those social and economic interactions. Although they represent wide experience due to their knowledge of sustainable use of genetic resources (e.g. different varieties that can be obtained from the seed of habanero chile), agribusinesses prefer to work with researchers for the application of modern technology. As it is noted, learning for economic and innovation purposes is a simple way to see learning interactions among these players; nevertheless, learning for innovation should also be oriented to social and ecological benefits, including the participation, promotion, and protection of local farming knowledge. Thus, knowledge and learning networks can emerge not only to generate technological innovation for farming that reaches national or global markets, but also generate and move knowledge and innovation through and from multiple directions to restore rural communities and farming based on sustainability principles (Potts, 2010).

According to the executives, there are many benefits of learning interactions, including the introduction of diversified products to the market with good quality, high competitiveness, economic returns, and social impact. The last benefit was suggested by Milbrath (1989), learning for sustainability should analyze present and future impacts and encourage civil society to participate in the decision making processes. One of the executives indicated that many projects and services offered by his institution are focused on producers, to increase their trade competitiveness, which is one of the principles of development. This includes increased monetary return, plant management savings, and agricultural techniques. The collaboration with agribusiness through the identification of needs or specific technological opportunities should also set. In any case, technology transfer agreements are needed in order to receive revenues. In fact, this executive emphasized “collaboration is about filling a community need and learning from others” (EX2). Collaborating should include

compliance with quality standards, but also sustainable development and improvement of the environment (EX9). Learning should focus on achieving better quality of life and reducing environmental impact. For example, an alumnus commented “when working with producers would solve an immediate problem through applied research, it is important to consider them in the solution process by generating ideas that improve their cultivation and the environment” (AL3). This alumnus commented that many researchers and farming consultants interact with smallholders with the idea of transferring a modern technology, but they are not open to what small farmers offer, such as traditional techniques. Scientists usually think of imposing a modern technological innovation, but smallholders have the ability to transmit their own ideas and knowledge on the management of the crops. For instance, traditional and small farmers are those who have preserved the germplasm bank in a traditional way through trial and error, that is, through experimenting with seeds for many years (EX7). This practice also has a relationship with their cultural and heritage practices, which should be recognized and protected. For this reason, it is crucial to empower civil society (local farmers) in learning, in policy formulation, and decision making processes (Sinclair et al., 2011).

The integration of the scientific and traditional knowledge is seen as ideal; however, it is considered difficult due to cultural differences. For instance, three executives mentioned that modern and traditional knowledge can be integrated, but it is difficult to do so because in agribusiness most scientific knowledge is applied to production processes. As well, this fusion does not occur due to the lack of economic resources to carry out joint projects and because farmers use their own conventional or traditional technology (EX9, 7, 5). For small farmers, daily practice is the best school one can have, but they recognized that scientific knowledge is also important. They usually do not reject participating and exchange information with researchers; however, one of them stressed that “this integration should not be about money or to get rich, it is about being more efficient with the use of our resources, and how we rescue our social and ecological values for feeding” (SF1). It is not about neoliberal reality, it is about vitalizing local food economy and grassroots initiatives (Norberg-Hodge et al., 2002).

In addition, respondents indicated that some problems arise when working with other local players. Many researchers and executives mentioned that there should be a change in attitude and willingness by all stakeholders to create an integrated learning environment. For alumni, the main problem associated with such interaction is the distrust among small producers and the adoption of a new technology due to the lack of financial resources. Most researchers noted that institutional policies and sometimes professional jealousy are the real problem. For example, diverse actors have priorities in terms of institutional commitment, funding, and little time to cooperate with others. However, a researcher reported that the problem is entrenched attitudes and mismanagement of time (R5). In fact, these learning challenges have support in the literature on complex learning and knowledge transfer inside social groups and systems. Milbrath (1989) mentions that in order to learn, a social group should overcome social and financial barriers as well as learn values from others. However, Sinclair et al. (2011) state that learning in social groups can result in new ways of being and thinking, making better decisions. With a good attitude and desire to collaborate and create knowledge, learning networks could be beneficial and productive for all local players. Here I will describe the benefits in three categories: a) the creation of inter/multidisciplinary groups, b) knowledge and learning networks, and c) the integration of scientific and traditional knowledge, as well as some learning and networking problems when people associate.

#### **4.3.1 The Creation of Inter-multidisciplinary Groups**

The opportunity to build inter/-multidisciplinary groups is to leverage the knowledge flow of different disciplines in reaching a common goal. It is an open door to dialogue, discussion, and share experiences and ideas for making better decisions. In this sense, an alumnus stated “the benefit of learning would be to know what need or problem is being investigated, bring new information to producers and researchers to create and implement better tools, and propose possible solutions. The importance lies in updating and connecting all actors to support every element in the product system, especially farmers” (AL1). For this reason, when many people are engaged in basic, applied, or technological research, information and learning can be complemented and strengthened. Thus, the integration of different disciplines in joint technological networks can allow a more proactive and

interactive innovation environment (Chave et al., 2012). Small farmers indicated that an individual never stops learning and sharing, as well as this is good because it is easier to identify farming needs and possible solutions. For example, a Mayan farmer said that he shared his planting problem with a researcher, and as a result, he could improve his crop through plant nutrition training (MF2). Thus, it is important to share information and experiences with other colleagues and experts to learn in a systematic way (triple loop learning), for both awareness of the local farming situation and for building enhanced relationships. Similarly, another Mayan farmer stated that “occasionally an engineer comes to talk to me about production and we exchange opinions and suggestions” (MF1). This is a form of translating knowledge and know-who, when producers and researchers gather and share information and problems. A small farmer reported that some years ago, they formed cooperatives to consume what they produced in the experimental crops, but now with the introduction of new technology and farming techniques, this model has almost disappeared. These cooperatives included the participation of students and professors along with farmers in their communities to promote and preserve eco-cultural farming (SF1). Conversely, a researcher indicated that in the case of small producers, it is not their priority to participate in research because what they want is to cover their basic needs (R1). In general, the perception of researchers is that there is little interest in learning interactions and interdisciplinary research inside the primary sector.

An alumnus mentioned that “the participation of all players is needed, the capacity of all with a great will and desire to improve agriculture is essential. The key word is will; believe that our participation and contribution is valuable and essential” (AL1). Collaborating with researchers and technicians is important, but collaborating and learning from producers is crucial because they have a lot of experience, they farm for a living, and make decisions based on their perceptions, experience, and intuition, this alumnus emphasized. An executive mentioned that interacting is fundamental and that collaborating to generate knowledge is one measure of a project’s success. A collaborative team should be integrated by various specialists towards fruitful and sustainable alternatives for agriculture (EX2). She also said that her institution is collaborating with an NGO under a scheme of learning communities. This interaction includes the analysis of diverse

agricultural topics along with the exchange of different point of views. Then, the same scheme is being implemented in her institution, creating multidisciplinary groups and knowledge networks because one actor definitely cannot know and do everything. These networks can help achieve common goals and address issues broadly by inviting different local and global players (EX2). In this region, I noted some collaboration among HEIs, research centers, and public institutions. For example, researchers and students of the Technological Institute of Conkal are collaborating with other researchers from the CICY and other HEIs through research projects focused on biotechnology. Many of these projects have been funded by the CONACYT or Fundación Produce. In fact, the CONACYT has published all biotechnological projects carried out the last 10 years in the region. The generation of knowledge and the intellectual capital that enriches the province can be seen more frequently among researchers and students. Hence, the socialization of knowledge (from tacit to tacit knowledge) is evident. However, the translation and externalization of knowledge (from scientific to traditional and vice versa) is occurring in informal ways (from researchers or professors to farmers). This collaboration means that at least two disciplines and local players are brought together to solve sustainability problems. In the case of small farmers who have similar status, culture, language, and problems, they tend to share information among themselves because they trust one another. This form of learning is very common, especially in rural and farming communities where farmers gather and share information in the park during evenings. When they have a bigger problem, they usually turn to the agricultural community leader for a possible solution. For example, a Mayan farmer told his story: “I was dedicated to planting indian papaya, but my production was not good; I watched my neighbor who was producing good sized papayas; so, I went to ask him what he was doing to get such good product; he explained, but it did not work. Then, I went to ask another neighbor and others, until after several experiments I had a very good production of papaya. So maybe this is learning for innovation” (MF2). This indicates that there are other ways of collaborating and learning, either through informal or formal means. The externalization of tacit knowledge has the goal to share personal beliefs and experiences with others; it is part of a contribution (Nonaka, 1994). However, it is also important to recognize that these interactions and networks can only be achieved when some barriers such as distrust and disintegration among local players are overcome.

#### **4.3.2 Knowledge and Learning Networks**

There exist both learning interactions and knowledge networks that support this product system. The advantage of having learning networks is the capacity to build local innovation system with a focus on promoting social, ecological, and economic benefits. The importance and benefits of learning interactions depend on our capacity to share experiences and practices, as well as the application of new methods and knowledge to common problems (AL2). “For example, as a horticulture consultant to the community I have the opportunity to collect experiences from other producers and inform problems and needs of the product system” (AL2). Another alumnus pointed out that learning networks and sharing experiences with colleagues can be useful in practice, especially when everybody can help solve a problem by applying a new method or knowledge (AL3). Collaborating and interacting on joint research was identified by researchers as one benefit of learning interactions. To this point, a researcher indicated that “many colleagues are working in laboratories without realizing that communities have needs and complex problems, so sometimes we are doing research that is not as useful to practitioners” (R7). Similarly, another alumnus said that “collaborating with several people increases know how and know-who” (AL1). Incremental knowledge and learning would benefit all stakeholders, especially producers who apply and use new technology as a result of such learning interactions. Another researcher stated that an advantage of collaborating and learning would be the establishment and consolidation of a food system in the region (R4). Thus, creating this link would benefit the producers as they apply new knowledge, but they also benefit other players in the product system by offering feedback to generate more and better ideas. This kind of knowledge is a combination, where people can generate new knowledge through social processes (formal or informal) and apply triple loop learning (social networks). This fact involves explicit knowledge through social mechanisms, including social media and incubators (Nonaka, 1994). Two researchers noted that “there should be a knowledge network that might be moving in different directions, those who are generators, those who are transferors, and those who are engaged in the process.” The benefit of learning interactions would be to have greater economic and social impact on local

communities ((R1, 5). It depends on the scope that knowledge development and transfer is given. This means that academic research and teaching should be enriched by the industrial/primary activity, and vice versa. Thus, learning and absorbing knowledge should occur among all participants in multiple directions and through a dynamic interaction among multiple players (top-down and bottom-up) (Chave et al., 2012).

For intermediate farmers, the benefit of learning networks is associated with improved production efficiency, less and better use of natural resources, and greater depth of knowledge for sustainable development. One farmer said “the benefit is to get better knowledge and supplement information about the product we are planting. This implies that we would need more technical knowledge and innovative ideas, which require greater interaction with other actors” (F1). Similarly, a farmer indicated that the key is to get together and integrate all actors. “If we are going to compete in a new market with new demands, it is better to work together through formal or informal learning processes” (F3). For instance, another intermediate farmer clearly emphasized that a technology and technological packet generated in research labs should be known through farming networks. It is time to open the doors, interact with other regional actors, and put the required technology into practice (F2). Understanding the advantages of having a knowledge network is obvious for all stakeholders. Many players are beginning to create synergies through these networks, generating and transferring knowledge in a formal or informal way. However, problems were recognized by the participants as a barrier for the generation of knowledge and learning network. Two researchers indicated that it is very complicated to gather all stakeholders together and work on a single project. They do not know any case study, where researchers generate a technology, producers apply it, and entrepreneurs sell the final product (R4, 1). Thus, the link among stakeholders is disjointed. According to most executives, the problem with interacting for learning and transferring knowledge is that research and education does not reach producers. Research should be put into practice, where farmers participate in the development of innovation and sustainability through the externalization of knowledge. “Collaborating would reduce risk and uncertainty for farming. But, this linkage is not working due to a lack of collaboration, education, and training at all levels” (EX6).

A good example is when the habanero chile product system was created in Yucatán. A civil association between intermediate producers and other agribusiness had already been created in the early 2000s; its goal was to boost production of the habanero chile in the province. Then, the government convened researchers from several public institutions and farmers from the Chile Habanero de Yucatán A.C., at the request of a Yucatecan entrepreneur for consolidating the product system and seeking the certification of Yucatecan habanero chile internationally. The aim was to unite efforts and knowledge to achieve certification through the recovery of native seeds and create a seed germplasm bank in the province. As a result, an initiative of a joint project called "the original certification of the habanero chile" was established in 2005. More than 35 researchers, agroindustry, and the provincial government were working to get this certification. These efforts paid off with the approval of the international certification of Yucatán habanero chile (CONCYTEY, 2009). The provincial government began to support small and medium farmers through various programs, including greenhouses, tools, coupons for purchase of agrochemicals and other inputs. Nevertheless, the government did not care about creating a collaborative and learning synergy, including local players (small and intermediate farmers, agribusinesses, and researchers), infrastructure, and adequate policies. Many small farmers eventually abandoned their plots due to lack of resources, production costs, market price, risks associated with climate, among others. Only intermediate farmers who had more financial resources, relationships, and education could continue their production. This is an example of the influence of capitalism; it imposes contemporary practices in agriculture as a single economic model for implementation; instead of integrating other practices such as knowledge networks (farmers, researchers, students, alumni, agro industries, and government) that may promote a better balance among economic, social, and environmental benefits of farming communities. The fact was that there was not an axis coordinator and a well articulated network of learning and knowledge. Even researchers began to have trouble working together because the economic incentives and funding for research and innovation are assigned and evaluated by a researcher, not by a group or network of researchers, one executive indicated. Indeed, this executive commented that he does not know any of innovation and research system that includes the association of



several researchers along with other local actors and knowledge networks, as a relevant criterion in the allocation of resources and funds.

#### **4.3.3 The Integration of Scientific and Traditional Knowledge**

Integrating different types of knowledge, including scientific and traditional is part of a social process, where the interaction of people and institutions allows the transmission of knowledge. In general, traditional knowledge has not been considered as important as scientific, due to the lack of evidence and organization to document and store knowledge (Torri & Laplante, 2009). Nevertheless, traditional knowledge in agriculture can open new ideas and opportunities for achieving local sustainability goals. For alumni, knowledge of local farming practices is valuable because it leads to preservation for current and future generations. As a result, the combination of these two types of knowledge (scientific and traditional) can result in better outcomes. Similarly, an alumnus mentioned that traditional and scientific knowledge cannot be separated because “traditional knowledge is an accumulation of information and experience over hundreds of years. For this reason, working all together to face environmental problems in our communities is ideal. However, these are not fully engaged in the present” (AL3).

An executive said that it would not be correct to discard the knowledge generated by traditional producers, the way they solve a problem is so practical and at such a low cost that it would be illogical to change practices. In fact, “we have learned from them how to manage a crop, what we do is to give it a scientific basis” (EX5). However, intermediate farmers noted that some traditional farmers are still not open to new techniques, although they realize these are necessary. Agriculture is delicate and complex work. Thus, it is important that traditional farmers are open to new opportunities because now everything has changed, and they do not know everything, an intermediate farmer indicated.

Intermediate farmers understand that a combination of innovations is needed to get optimal crops. Nevertheless, they concluded that it is very difficult to collaborate with traditional and local farmers because these farmers do not think and act as agricultural entrepreneurs. According to researchers, integrating scientific and traditional knowledge is important, but difficult to combine as well. Three of them held that it is difficult to talk directly because

they speak two different languages (R1, 5, 10). For some researchers, this combination is difficult because each group has different knowledge and approaches to the practice of farming. Researchers write scientific procedures and provide evidence (externalization of tacit knowledge) intended to improve the production systems in agriculture. But for traditional and local people, the most difficult task is the externalization of tacit knowledge because oral transmission and empirical experience are usually the means used among them. Indeed, Hoffmann et al. (2007) realized that disagreement can occur when scientists and farmers associate, but both actors can eventually assume specific roles in order to externalize tacit knowledge.

Local and traditional farmers can transfer knowledge about land management and energy savings, as many of them schedule their agricultural activities according to the Mayan calendar, or weather fluctuations (using rainwater), measure the degree of soil fertility, and use organic (natural) fertilizers and pesticides as part of their reduction of energy. Many of them can also transfer information about the medicinal effects of many botanical species, including the habanero chile with its native varieties, and how these varieties behave in different climates. Polyculture systems and home gardens are other examples of knowledge transfer from the bottom up that can be leveraged to achieve sustainability in agriculture (SF1, AL1, EX5, EX7). Probably, this does not mean higher economic gain, but it means that better integration and protection of collective knowledge (scientific, local, and traditional) may lead to social, natural, and economic justice. However, it is difficult to provide proper recognition of local and traditional knowledge as the basis for the development of technological innovation, because scientific knowledge is known and applied universally (R10).

A researcher mentioned that the trend is back to traditional management because small farmers manage three or four mecatres by implementing inter- and multi-cropping, using fewer chemicals and different farming techniques (R9). Similarly, a researcher pointed out that traditional people handle fragmented cropping with different varieties providing genetic variability that it is not found in monoculture (R1). In this sense, knowledge can be generated from empirical and scientific evidence. However, the discovery of new seed

varieties or a novel practice through empirical knowledge of traditional farmers is not protected under copyright law. Internationally, there is a law that protects traditional knowledge, especially the legislation that focuses on the use of genetic resources and biodiversity (Correa, 2001). In México, the International Nagoya Law that protects the knowledge generated by traditional and local people is still not effective (Instituto Mexicano de la Propiedad Industrial ‘IMPI’, 2015). A researcher mentioned that “we must protect the way in which we interact with small and native farmers, making them part of what we are doing and let them know the important role they are playing in doing this. They should be our allies, maintaining biodiversity and producing at small levels” (R7). Additionally, an executive pointed out that traditional and scientific technology can improve the plant quality and quantity, increasing the local farming productivity (EX1). Thus, through the joint demonstration and validation that crops can reach good level of productivity, scientists and traditional farmers can combine knowledge for better results. Cannarella et al. (2011) reported that practices and techniques from traditional knowledge into modern science by creating technology for local communities’ development can be integrated. Another executive said: “I had the opportunity to see how a Mayan farmer recorded innovations in corn crops and I was stunned how they made agricultural experimentation with varieties of corn, how they planted, fertilized, and managed uncertainty during a season. Then, the leaders disseminated this knowledge to the rest of the community. Thus, integrating both scientific and traditional knowledge would be the sum of wills and strengths” (EX4).

Likewise, an executive mentioned that her institution has a Mayan cultural area that helps to translate, transfer technology, and combine it with modern knowledge. This fusion is important for achieving sustainability goals because we are respecting the culture and the language (EX2). A researcher said that traditional farmers were the first to learn how to make improvements in agricultural production. The difference is that researchers handle scientific knowledge for the study of genes, and local and indigenous farmers do it in an empirical manner (R7). Although much of this knowledge comes from traditional agriculture, in this region few small and native farmers have patented their products, since they would have to be registered as individuals or corporations in the tax system, in order to

register a plant variety (Gómez & del Villar, 2009). The challenge lies in the protection of the processes and products that the indigenous and local farmers generate. Intellectual property procedures for local and traditional knowledge should be reviewed, implemented, and operated. Another challenge is creating a better dynamism and collaboration with traditional farmers through new relationships, allowing them to be recognized and protected by copyright law, and promoting their engagement in the innovation, research, and decision making process for new farming systems and sustainability. As Snapp and Pound (2008) indicate, the significance of creating participatory learning and action research through formal or informal experiments between researchers and farmers. Thus, the current farming innovation in this region, which is based on technology transfer and farmer first, should be reoriented to build a more interactive innovation approach for sustainable agriculture, and the recognition of traditional knowledge for innovation and sustainability. Three broad areas were identified in learning interactions: 1. the creation of inter- and -multidisciplinary groups, 2. networking of knowledge and learning, and 3. the integration of scientific and traditional knowledge, as indicated in table 4-5.

These three areas are the result of organizing all stakeholder responses according to frequency and relevance. As can be noted the perspectives of stakeholders are varied and similar regarding learning interactions and the integration of scientific and traditional knowledge. Most stakeholders noted that traditional knowledge is valuable, because it is a combination of experience and the application of traditional techniques to modern farming. However, integrating traditional and scientific knowledge may be difficult because these actors are completely different, and scientific knowledge predominates over traditional.

Table 4-5  
*The Benefits of Learning Interactions*

The creation of inter-multidisciplinary groups	Networking of knowledge and learning	The Integration of scientific and traditional knowledge
<p>The interaction allows having broader and deeper product knowledge.</p> <p>The application of knowledge and technology, which implies the improvement of such technology over the product through receiving feedback from users.</p> <p>Efficiency in term of faster and better use of resources through the use of institutional efforts, knowledge and infrastructure.</p> <p>Working with different institutions and people allows crop management holistically.</p> <p>Greater social impact and better results.</p> <p>Efficiency in terms of production, less and better use of natural resources, and greater depth of knowledge for sustainable development.</p>	<p>Identifying real situations, problems and possible solutions through greater sharing experiences, knowledge and resources with others.</p> <p>The diffusion and application of technology generated by this network.</p> <p>A vision of partnership and alliances in order to leverage resources and market supply, resulting in benefits to the producers.</p> <p>Share the same mission and vision. Perfectly an articulated network.</p> <p>The development and transfer of knowledge should be in multiple directions (from industrial to researcher, from producer to industrial or researcher, etc.).</p> <p>Farming communities may be benefited from knowledge and learning network.</p> <p>Formal and informal means of gathering and sharing information.</p>	<p>Integrating both scientific and traditional knowledge would be the sum of wills and strengths.</p> <p>This fusion is important for sustainability through respecting the culture, the language, and the environment.</p> <p>This is not about money or to get rich, it is about being more efficient with the use of our resources, and how we rescue our values for feeding.</p> <p>Traditional and scientific knowledge cannot be separated because traditional knowledge is an accumulation of information and experience of hundreds of years.</p>

For illustration, three executives said that the problem with small and traditional producers is that they do not adopt a technology and innovation because they do not have enough capital to apply such technology, and so they prefer to apply traditional methods (EX3, 8, 7). In this sense, the externalization of tacit knowledge is not being applied. For small farmers the problem is different, but seemingly simple: a clash of culture and education.

Their lack of scientific understanding and their non-involvement in the research process makes transmission of knowledge difficult. In turn, intermediate farmers indicated that collaborating with small farmers is complicated because it is a period of generational change, where traditional (“old”) beliefs do not fit with new production schemes, regulations, and market demands. They reported that more than half of the small producers are not prepared for new changes and demands. In addition, these stakeholders emphasized that clear policies and social rules about learning for innovation, market demands, and sustainability do not exist; however, even if such policies and rules existed, no one is interested in following them. One of them concluded “the habanero chile product system is disarticulated, but some intermediate producers are interchanging knowledge and experiences about the balance of the environment, market, and healthy agriculture in a coffee shop” (F4). As Stagl (2007) and Mezirow (2000) states, learning can contribute to understand complex social systems based on beliefs, experiences, and new ways of thinking and interacting. Thus, diverse types of knowledge can be integrated to improve the management of natural resources, agricultural techniques, and resolve current agricultural and sustainability challenges.

#### **4.4 Barriers and Opportunities in Building Local Innovation Systems**

When stakeholders were interviewed regarding barriers and opportunities for the creation of local innovation systems similar responses concerning learning interactions were found. Some barriers include lack of alignment of public policies and programs relating to producer needs, malfunction of such programs, and a lack of a supportive structure. Some of these barriers were encountered in learning interactions, such as lack of willingness, attitude, and general resistance. One researcher commented that it is a mistake to operate on the basis of six-year plans because there are no clear goals and guidelines for the long term regarding innovation plans (R9). One executive pointed out that “there is a lack of integration in different segments of the innovation process, i.e. there is institutional disinterest to complement know-what and know-how” (EX1). Thus, if there is no union and no one is interested in combining strengths, it will be difficult to create local innovation systems. The opportunities focused on solving the above mentioned barriers. Responses in terms of opportunities include consolidating the production system, integrating

stakeholders through a coordinating body, a bottom-up strategy to locate real needs, and establishing a knowledge network to move in innovative directions. An alumnus indicated that “government should align resources and capabilities with the problems of the communities. Then, align public programs to address the different needs or problems and invite all stakeholders to participate in their correspond part” (AL4). One executive commented that it is necessary to create a methodology that allows institutions to measure the results and the technological innovation impact in the short term (EX7). This indicates that many of those interviewed realize how these barriers could be resolved; the most difficult part is to break down the attitude and will of people, and how complex is to create, implement, operate, and measure the impact of innovation systems towards sustainability. Below, the main responses given by stakeholders relating to barriers and opportunities for building innovation system are described.

For alumni the main barrier is resistance among producers and other players including ignorance, lack of knowledge, lack of information, and cultural differences. One explanation for this barrier was suggested by Cannarella et al. (2011) reporting that enhancing local confidence, respect for local knowledge, and the support of creative use of local materials can increase collaborations among farming stakeholders. In contrast, researchers indicated that there is a lack of coordination and alignment of the entire production chain, especially the agricultural sector. For instance, one researcher and some intermediate farmers said that governmental and institutional policies are not aligned with the needs of producers; these are generally outdated and poorly coordinated (R6, F4, 5). Three executives said that many farming programs that government supports, introduce materials from national and foreign companies, but that local materials are rarely used. In this sense, it is cheaper for an industry and some producers to import a raw material to reduce cost, which in turn reduces the cost of production (EX7, 9, 10). In addition, two executives pointed out that there is a lack of integration in different segments of the innovation process; no one is interested in socializing and externalizing tacit knowledge. Thus, the creation of knowledge flows will be difficult because there is a gap between academic bodies, business culture, and society engagement, which needs to be addressed. Similarly, one executive said that innovation systems are designed for academics

(researchers); these systems join a large number of universities together (researchers and students) with private and public institutions (alumni researchers) for working on identified lines of research (EX4). However, it is not clear if these research lines consider current problems or needs from farming sector and sustainability goals.

For some researchers additional barriers include limited economic resources; most producers cannot invest in infrastructure, research, and training. Another researcher indicated that many local players do not know what innovation is, so most people understand innovation as something new; as a result, they focus on creating something new (R5). For instance, one executive mentioned that “if the goal of innovation is to improve the quality of life of communities, it has to be feasible, implementable, and measurable; but how to measure such impact if we do not have a good structure?” (EX7). Likewise, two executives and intermediate farmers agreed that the main barrier is structural because we continue having poverty in farming communities. They concluded that there are too few institutions oriented to prepare people, there is a lack of resources, a lack of information and technology transfer, a lack of interest in agriculture from governments and institutions, and a lack of markets that support sustainability goals for production and consumption. As a result, the region does not have an innovation system well-articulated toward a common vision. Small farmers reported that main barriers are associated with a lack of infrastructure and resources and a lack of training and education. In fact, they have not seen any knowledge network focused on solving problems such as pest control or crop improvement. Intermediate farmers suggested that farmers are the basis for innovation in agriculture and there is a lack of support for that base. For example, not many farmers are trained to understand production process traceability (the planning and monitoring of a production chain) (F1). Furthermore, these stakeholders identified as a barrier the complexity of farming system, “a consolidated and healthier system is still not created, even for sustainability because the relationship that exists in farming are so complex that when a hole is opened in the ground, something is damaged” (F4, 5, 2). An example of a barrier was given by an executive: “I think it is better to teach producers instead of giving them a monetary or input support for their farming. It is something that government should be aware of because I have seen how they implement public programs for agriculture.



Producers receive support of fertilizer, seed, or any other input, and in many cases this support arrives late because producers have already planted, the cultivation has been sowed for eight weeks, and then, that fertilizer ends up in the canteen, or unfortunately curing a disease when a family member is sick. Then, the programs fail to arrive where it is intended. There is public support to producers, but it is poorly channeled, only sixty or seventy percent of such support goes where the problem is” (EX4). This point has been examined by Karlan and Appel (2011) who provide some examples about public programs that do not work appropriately, and the need for innovations to address unsustainable practices.

Opportunities for alumni and intermediate farmers would include establishing a common vision for all stakeholders at all levels, leveraging the strengths of institutions and people, as well as generating and introducing gradually sustainable local actions. Two alumni indicated that education is necessary, particularly regarding the importance of developing, integrating, and learning from community projects (AL4, 5). Most researchers and alumni mentioned that public programs and strategies should address community needs and improvements, and invite multiple stakeholders to participate in their identification and solution. Spielman and Birner (2008) developed an agricultural innovation framework where the farmer is an active player inside the knowledge network. This integration opportunity should lead to new ideas focused on creating social, economic, and ecological benefits. Projects generated within local innovation systems must provide benefits to communities to improve social and ecological conditions. For example, alternative uses of hog farm waste could solve an ecological issue (R8). To this regard, two researchers emphasized that a change of perspective at all levels is needed, because the actual innovation schemes are not focused on social or ecological welfare (R7, 9).

For executives and intermediate farmers, another opportunity lies in non-linear collaboration, learning, and transfer of information among local players, especially between researchers and producers. One of the executives said that every local community should have an agronomist to support producers and be the link with research centers (EX7). Similarly, small farmers reported that a community consultant can support and advise

producers and integrate farmers. An executive concluded that social innovation can help sustainability, but not technological innovation. For him, social innovation establishes social learning interactions among different local and rural communities, but social innovation is not found in regional or national innovation systems (EX4). However, Alcamo and Bennett (2003) say that the creation of technology and scientific knowledge can have a positive impact on socio-ecological systems, including clean water and food security. Thus, institutions should have a transformation of policies, research, social learning, and the transfer of technology that support sustainability goals through social and ecological actions.

The above responses were consistent with SWOT analysis: participants mentioned that government should establish a coordinating body that regulates the entire system because current provincial and national committees of this product system (habanero chile) are working in isolation and are fragmented. The provincial committee, that represents the majority of small producers, has little direct interaction with other local stakeholders such as industry or research centers. In addition, the identification of needs and decision making processes are still carried out by top-down players, society is not participating in these processes. There are some open forums to promote society's participation, but they are isolated. Only intermediate producers who have the resources and top-down relationships are involved in the consultation forums organized by Fundación Produce to identify agricultural sector needs. This NGO transmits those needs to research groups that are able to develop technology. Smallholders do not participate in these processes. An executive added "thinking about small farmers as entrepreneurs is a myth." This condition is because they are not interested in intensive production, they do not have enough training, or they do not have the resources for this type of production (EX4). In this sense, the necessary conditions for quintuple helix do not exist because civil society and bottom-up players are not participating in knowledge networks. The same executive also indicated that the type of soil and environment that exists in some parts of the Yucatán Peninsula is another crucial aspect. Production cannot be fully mechanized and nor become intensive due to stony soil; as a result, many small farmers are still practicing traditional agriculture. In fact, "the Northern Yucatán people have retained its culture, language, and lifestyle due to this type

of agriculture” (EX4). However, traditional practices are not always seen as functional in the contemporary world because these practices might not be transferable broadly (Dei, 2000). In this sense, technological innovation can be seen as colonizer that does not properly integrate the creativity and innovation of local and traditional people in favor of sustainability (Gómez & del Villar, 2009). Thus, there are critical issues to be addressed, including policies of technological and non-technological innovation in agriculture aligned with copyright law, the integration of multiple players with diverse knowledge to optimize the externalization of tacit knowledge, and a triple loop learning inside the system, where the respect of diverse beliefs, values, and actions should be considered as an asset to achieving sustainability. Table 4-6 summarizes the main barriers and opportunities in building local innovation systems described above, in order of highest frequency.

Most stakeholders indicated that the opportunity of this system will be realized with the union of small and intermediate producers, HEIs, research centers, industry, and government to join strengths and support the product system. The problem arises when provincial and national governments are changed every six years and the continuity of objectives and courses of action are interrupted. In addition, there are political and personal interests that prevent support for projects or programs that began during any six-year period, which will probably not be applied in the period that follows. The main barrier is public programs not aligned with real needs and problems.

Table 4-6

*The Identification of Barriers and Opportunities in Building Local Innovation Systems*

Barriers	Frequency	Opportunities	Frequency
Lack of the alignment of public policies and programs relating to actual needs.	10	Align the vision of all product system stakeholders through a coordinating body.	8
Poor design and malfunction of programs.	9	Bottom-up strategy to locate real needs.	8
There is neither a good producer organization level, nor effective coordination at state level because there are no clear rules.	7	Establish a network of knowledge to move in different directions, those who generate, those who transfer, and those who implement.	7
Lack of a better structure and training.	7	The establishment of a food system with high quality standards.	5
Lack of willingness and attitude due to ignorance and resistance among producers.	5	A change of perspective at all levels, because the actual schemes are not focused on social or ecological welfare.	5
Lack of financial resources.	5	Introduce gradually sustainable actions at local level.	4
Lack of information. People have many questions, both those who generate and those who adopt innovations.	4	Projects generated within the innovation system must provide benefits to communities to improve social and ecological conditions.	3
The small farmer does not think and act as entrepreneur.	2		

Many of those interviewed pointed out that barriers may be resolved; the most difficult part is to break down the attitude of people and the complexity of creating, implementing, operating, and measuring the impact of innovation systems for achieving sustainability. Some stakeholders confirmed that these situations make it difficult to consolidate local innovation systems because no one is interested in legislation, policy development, system alignment, and learning outcomes. As well, there is a lack of coordination and evaluation to

help manage sustainability activities and actions within the system. Thus, a quintuple helix model may represent an opportunity in the future but presently the conditions cannot support such a situation. However, informal and formal knowledge networks are emerging not only in this product system, but in other sectors as well.

#### **4.5 The New Role of Higher Education Institutions**

Research centers and HEIs are actively involved in scientific and technological pursuits. They receive funds from government and some private corporations to ensure research is informing development. This section will address the following question in order to respond my third objective: What role HEI should play inside an innovation system and sustainability innovation? When I asked this question I realized the enormous potential and capacity that HEIs have to facilitate innovation that contributes to sustainability and local development. But, at the same time I noted the problems they face and how they are addressing them. HEIs play a crucial role in knowledge generation and innovation activities for regional development. Caniäls and van den Bosch (2010) argue that HEIs situated in suburban and rural areas exist in part to revitalize local economies and the well-being of society. However, most stakeholders agreed that a lack of a socio-economic revitalization in local and rural communities exists because new graduates do not want to pursue a farming career. An alumnus commented that what is happening is that many graduates are seeking status as professionals and not choosing farming. “It is needed people and alumni who enter the agricultural sector, solve problems, and pursue continuous development. But, we are far from understanding this behavior culturally” (AL3). Moreover, a researcher mentioned that HEIs and research centers are fragmented; one group generates basic research and the other group pursues applied research (R5). Another researcher indicated that research must have a purpose, whether basic or applied, and the researcher has to go where the problems are (R7). To this regard, an alumnus said that HEIs should be “at the vanguard of innovation, to combine primary production with agro-ecological systems, in areas that allow farmers to improve production. The goal would be maintaining ecosystems, producer culture, and achieving a self-sustaining society that participates in development and innovation” (AL4). In this section, the responses of stakeholders regarding the new role of HEIs in agricultural innovation systems for sustainability were classified into three

categories: knowledge generation, knowledge transfer, and contribution to sustainability, with special emphasis on the creation of an innovation link among these three aspects and the involvement of multiple stakeholders. These descriptions are presented in order of highest frequency in table 4-7. Methods for collecting information were interviews and SWOT analysis.

#### **4.5.1 Knowledge Generation**

Most stakeholders stated that the new role of HEIs is to take knowledge to places where it is required; in this case, farming communities, to improve their living conditions. Most researchers pointed out that knowledge generation should be linked to the real world and real problems, balancing both basic and applied research. Another researcher added “Universities should hold as their guiding principle for solving the problems of society; they should be the lever to boost the development of technology and science” (R9). Some researchers indicated that innovation has gained much importance and has to be generated in the classrooms of HEIs. HEIs should instill in students the creative sense and the creation of knowledge; although, this may not necessarily end in new technology or innovation (R1, 4, 8). For this reason, adapting curricula to the needs of the environment and society is necessary. Breznitz and Feldman (2012) suggest that universities should have policy related to the identification of community’ needs and doing research according to identified issues and recommendations. An executive commented that the new role of HEIs is building human capital and research, as well as having links with other institutions. But, the most important role is the training of people oriented to sustainability principles (EX7). To this regard, an intermediate farmer noted that education must systematically link scientific knowledge with ethics, logic, and honesty in order to improve production and consumption (F2). In the same way, two researchers noted that a new role is education regarding ethics and morality (R9, 10). For small farmers, linking theory with practice should be a vital function of HEIs, using two methods: basic information and practical experience. Another researcher said that HEIs should focus on efficient techniques with practice and a stronger link between theory and practice for better knowledge generation (R2). A small farmer stated: “I had the opportunity to collaborate with an institution of

tropical agriculture in 1970's. At that time, this institution had academic exchanges with other universities in the world, mainly Europe, and sent engineers to pursue a graduate program to enrich ideas such as hydroponics and the management of livestock in less intensive and exploitative manner, not for commercial use. The purpose was to be more efficient in the use of our resources, not to be rich and be more consumerist. Today, what is needed is to rescue important values for local farming by cataloging and storing methods that are useful or not. The education system got off the idea that the child may be playing to be a major producer, and the young man who has energy can learn to use his creative work in agriculture for his own benefit. So collaborating and playing can greatly enrich social learning and knowledge exchange" (SF1). In this way, strengthen the linkage of innovation with industry, academia, producers, and society to reach better social, economic, and ecological development would be a critical factor, some participants concluded.

#### **4.5.2 Knowledge Transfer**

Alumni recognized that there must be greater collaboration and transfer of knowledge between educational institutions and the production sector, as well as the ability to measure the benefits derived from this collaboration. Breznitz and Feldman (2012) suggest that learning experiences and improving skills for transferring knowledge include diverse formal and informal mechanisms (licenses and social networks). For instance, universities developing projects focused on sustainable issues should emphasize the generation, diffusion, and use of better practices across economic sectors. In this way, research projects will benefit producers, industry, and finally consumers (AL1). In addition, there must be an alignment and engagement between HEIs and society (AL3). Researchers emphasized that the establishment of scientific programs should be based on the application of knowledge to solve community concerns or demands. For this reason, HEIs should be articulated with business and create a triangle with producers to solve not only a problem in the primary sector, but also in the secondary and tertiary sectors. For instance, an intermediate farmer mentioned that "HEIs should have greater interaction with producers; they should visit them on their crops to see what it is needed, realize what problems they are facing, and investigate what the best solution can be without the use of chemicals that are not allowed

by quality and export standards. The main problem for most producers is pests. So if the producer has knowledge and the technological package based on organic inputs, to cope a pest before using a chemical, this would be a great opportunity for continuous improvement. Also, HEIs can provide guidance on how to maintain lower labor costs and how to use an organic product for weeding, as well as how to improve irrigation systems for greater yield. However, the agreements and relationships with HEIs do not always materialize” (F2).

In this way, one recommendation was to conduct applied research in partnership with rural people focusing on actual problems or needs, for which different types of knowledge and resources should be shared (R7). Two researchers emphasized that HEIs and professors have to transmit a new vision to students for running their own businesses (R4, 6). For one executive this is important because HEIs should promote the next generation of agronomists as farming entrepreneurs and provide them with opportunities and support (EX1). A researcher highlighted that “HEIs should be devoted to more than teaching; they should integrate technological enterprises, in which students develop their own production systems. For example, some institutions can be devoted to industrial businesses and others to primary or agricultural businesses; so, HEIs would be collaborating and contributing to the development of communities, increasing living standards and sustainability” (R4). For this reason, two recommendations were given by some participants: a) encourage students to be agricultural entrepreneurs and b) strengthen the innovation and entrepreneurship program in the educational system (R4, EX5, and F2). For instance, The Jagiellonian University in Krakow, Poland has established three centres of innovation. The Centre of Innovation, Technology Transfer, and University Development promotes qualified scientific projects for commercialization, essentially in the biotechnology field; contacts with businesses interested in technology transfer are also made. The Jagiellonian Innovation Centre was created as a technology incubator. The Academic Science and Technology Centre that is in charge of transferring and commercializing technologies generated by Krakow universities such as The Krakow Agricultural University. In this sense, the creation of networks starting with HEIs assisting as either an incubator or supporting the commercialization of a new technology, creates the opportunity to share



ideas, infrastructure, and informal interaction with other collaborators in the realm of regional development (OECD, 2008).

Unfortunately, the restrictions on patenting a product generated through social or academic networks are not so easy to overcome, because an institutional or individual registration is needed. Transferring knowledge implies two big challenges for HEIs: a) continue to transfer scientific knowledge to rural communities through patented technological packages with an economic benefit, and an emphasis on scientific evidence; or b) establish social-knowledge networks (innovators) through promoting an active and dynamic learning among all local players (including local and indigenous farmers). This action would need to seek appropriate mechanisms and policies to promote new legislation on intellectual property, e.g. transferring collective knowledge inside and outside networks.

#### **4.5.3 Contribution to Sustainability**

Most researchers indicated that HEIs must understand they play an important role in the development of the region, with a focus on sustainability. In this case, universities should consider sustainability goals (maintaining natural and cultural ecosystems) when research involves farming production and market aspects, an executive added. For executives, three new HEI roles are necessary: a) identifying high-impact projects that may revolutionize a production system, b) increase the quality of life for people who are involved in the system, c) support research on food and nutrition at the scale of local communities. The goal would be to increase production with the help of technology, and as a result, the producer would obtain their livelihood as well as adequate and healthy food. Another executive mentioned that “teaching people how to form social groups and teamwork is vital because this association has been lost. He explained that indigenous people tended to be communal, they were collaborative partners. With modern economic development, everyone is competitive; however, competition is not always necessary” (EX4). Intermediate farmers and other executives noted that universities should visit the most vulnerable places to understand local needs. “It is necessary to break barriers, know the farming activity, and see reality”

(F2). To this regard, Martinez et al. (2006) found that collaborative processes can lead to stakeholder-wide search for needs and solutions to social and environmental problems.

Moreover, intermediate farmers indicated that universities should invite and involve local people in the application of a new technique. Then, disseminate and demonstrate the benefit of this technique through public media, so successful learning outcomes can be replicated. Two recommendations were given by participants in the SWOT analysis: a) public policies aimed at applying innovations generated inside HEIs and Research centers to agricultural communities in support of self-sustainability, and b) recommend educational programs focused on participatory and multidisciplinary agronomical research, encouraging the development of sustainable inputs, processes, and outcomes. For instance, an executive said “If researchers can test and establish sustainable farming, in well-defined areas, allowing producers to produce what it is required, maintaining ecosystems, and the culture of the producer, although a producer does not necessarily has to be traditional to grow in small areas, then HEIs would be contributing to the economic, social, and ecological sustainability. However, the problem is structural, because most research is federally funded with orientation to monoculture activities. So researchers and producers should be thinking about another type of production system; this could be extensive agriculture in some areas, but in other areas it has to be less intensive and extensive, including a production mosaic at small scales (polyculture)” (EX1). In this sense, policy incentives motivating innovation and new knowledge, stimulating the participation of multiple local players, setting clear regulations, and boosting the skills and capacities of players can help to reinforce the structural dimension (Wieczorek and Hekkert, 2012). However, it is also needed policies and incentives to innovate thinking on reaching sustainability principles.


It is important to note that HEIs are knowledge generation and transfer centres within the regional economy. On one hand, HEIs hold the critical mass and intellectual capital devoted to scientific research; on the other hand, traditional practices where civil society and farmers generate an idea or technology is an important context within which HEI contributions must be made. As a consequence, both scientific and non-scientific knowledge should be part of this innovation system. In this way, grassroots initiatives are

part of non-scientific knowledge that may innovate for sustainability and build knowledge inside local innovation systems (Seyfang & Smith, 2007). Some researchers concluded that HEIs should play a more important role in generating and transferring knowledge.

However, most researchers reported that the funds from Fundación Produce are more oriented to applied research and technology transfer, while Conacyt supports more basic research (R1, 9, 4). For instance, none of these institutions recognize or allocate resources to research based on traditional knowledge, because it implies that the final product cannot be transferred, patented, and marketed due to the lack of a scientific and legal framework. Thus, scientific research continues receiving support through well established structural aspects (law, rules, and policies).

Table 4-7

*Three Roles of HEIs in Agricultural Innovation System*

Knowledge generation	Knowledge transfer	Contribution to sustainability
<p>Basic research.</p> <p>Identify needs through visiting communities and crops.</p> <p>Create a new dynamic with bottom players in regards to innovation and sustainability.</p> <p>Present alternatives of solution through research and projects.</p> <p>Training people in technique efficiency, but also in ethics education and sustainability principles.</p>	<p>Applied research.</p> <p>Better practice and technique involving local players.</p> <p>Enhance the creation of farming business.</p> <p>Disseminate, invite, and demonstrate a new technology.</p>	<p>Engagement, collaboration, and learning among diverse players.</p> <p>Solving needs and problems of local communities.</p> <p>Support the improvement of society's living conditions.</p> <p>Projects oriented to sustainable production including an ecological and social impact.</p> <p>Having technological enterprises that can contribute to regional and sustainable development.</p>
		

Thus, a well articulated link would be beneficial for both research groups, emphasizing the importance of collaborating and building learning networks. The benefits of using and

applying the technique, plus the benefit of generating data and information from basic and traditional research would not only contribute to community development, but also build knowledge networks. In this sense, the creation of innovation links among stakeholders would be ideal. Another important result is the fact that HEIs themselves can be technological enterprises and can also support the development of technological and farming businesses among students contributing to sustainability. To this regard, Carayannis and Campbell (2012) suggested that the quintuple helix model involves research and entrepreneurial activities developed in HEIs, along with civil society and other players, which have the opportunity to learn and transfer knowledge for sustainability. Thus, HEIs should promote the engagement and learning of top-down and bottom-up stakeholders around sustainable projects for better social, ecological, and economic impact. While HEIs of the region might not have well established knowledge alliances and do not have some structural capacities for implementation, it is time to develop a local innovation model to proactively impact their communities.

## CHAPTER FIVE

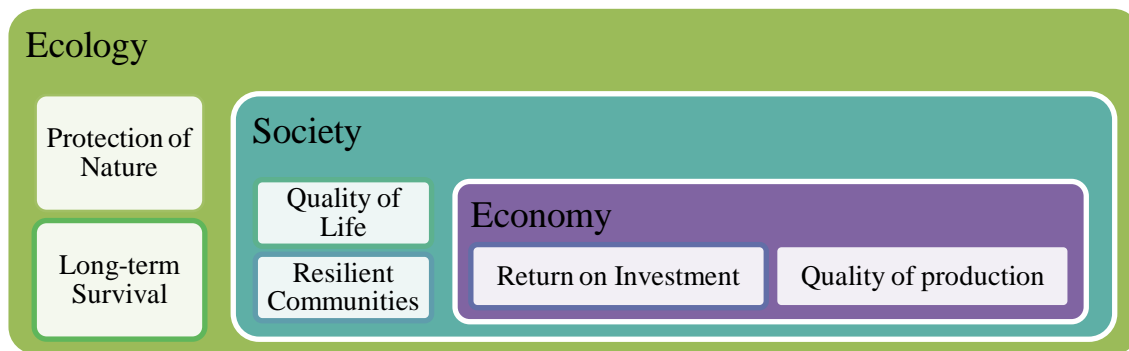
### DISCUSSION AND INTERPRETATIONS OF FINDINGS

The focus of this thesis was examining the contribution of innovation to sustainability. Such innovation systems at local levels include the interaction of multiple players generating knowledge and learning for sustainability. In doing this, *sustainability* and *innovation for sustainability* were explored. This exploration resulted in many diverse points of view and perspectives on the related terms. The study of a product system (habanero chile) represented a good opportunity to highlight the importance of building local innovation systems. This system was described as an interactive and dynamic system where multiple local players (top-down and bottom-up) interact for learning and generate and transfer innovation and knowledge supporting sustainability in agriculture. The analysis of HEIs allowed for the identification of an institutional role in innovation and sustainability activities. This chapter addresses both concepts (*sustainability* and *innovation for sustainability*) at a local level, from the perspective of multiple farming stakeholders, each representative of one of two distinct farming groups. The results indicate a divergent sense of how innovation can support sustainability in local agricultural systems. Multiple perspectives revealed that new technology and methods should support sustainability, but also innovation for sustainability should consider the ethical and social order around the product that is being offered to society. Local farming systems should be seen as important spaces for the generation of knowledge, innovation, and sustainability. For this reason, the main contributions that innovation may offer in support of sustainability at local level are presented. This is followed by the opportunities and challenges in building local innovation systems for sustainability. I also address why and how sustainability would be a relevant instrument for systemic innovation, considering it apart from knowledge generation and transfer, financial resources, and market functions. Finally, a discussion of learning interactions in local spaces among government, universities, industries, civil society, and natural environment and how that represents the quintuple helix model is given. The interpretation of findings supports a discussion of the complexity and challenges around sustainability through the lens of innovation.

## **5.1 Sustainability and Innovation at Local Farming Spaces**

In local agricultural systems, sustainability means maintaining ecological and human conditions over time and space. It also involves financial stability and market capacity to ensure reinvestment in the production process, and as a result, avoiding abandonment. The viability of the primary sector ensures better and fair incomes and continued interest in farming. Sustainability as a process emerges and evolves over time, in this case to preserve agro production systems for many years, in terms of economic return and biodiversity preservation. If there are local agro systems that are resilient over long time periods, they will support long-term production, which is particularly important for local farming communities so they can build a pathway to more sustainable farming systems. A more sustainable farming system would include the interrelated principles of sustainability (social, economic, and ecological). These sustainability principles would result in improved quality of life, resilient communities, and long-term survival. Robinson (2008) says that sustainability can be understood as the interrelation of ecology (natural resources to society), economy, and society (quality of life for all people through social structures of governance and values). Sustainability is then a holistic integration of environmental, social, and economic dimensions which include many other elements that support the well-being of local communities, including respect for local cultures, languages, traditional knowledge, better education, social rules, and human development.

Sustainability can be seen as a mix of basic needs and living standards, financial security and stability, and the will to protect nature to ensure economic and non-economic wealth for all. In many sustainability descriptions the environmental dimension prevails over the social and economic dimensions. This suggests that strong sustainability is guiding the knowledge of several stakeholders. Strong sustainability holds the environmental system as the principal axis for social and economic systems. Figure 5-1 shows the integration of categories of sustainability in agriculture, where my results indicated that ecology embraces society and economy, leading to strong sustainability. This integration might be seen as complementary to other sustainability frameworks (social, environmental, and economic dimensions).



*Figure 5-1. The integration of categories of sustainability in agriculture*

Experience and knowledge play an important role in describing and practicing sustainability because there are a range of lenses through which reality could be seen, especially in agriculture. Local farming systems are composed of institutions, communities, which are the spaces and places where diverse stakeholders create, produce, and consume. As a result, these stakeholders behave in accordance to social rules, financial resources, social actions, and beliefs. Thus, sustainability in local agricultural systems should be seen as a system that integrates various principles, beliefs, rules, actors, roles, and structures covering three broad areas: return on investment (economic), quality of life (social), and the preservation of nature (ecological). If one of these is not fully established / supported, then sustainability is unachievable. Furthermore, sustainability in farming also includes cultural and biological diversity, multiple ways of knowing, sufficient and healthy food, and long-term existence of the system in question, which leads to better or sustained quality of life. However, sustainability is seen from two different perspectives: a) those stakeholders who embrace better integration of the three principles of sustainability as a whole (holistic) perspective, and b) those stakeholders who see the prioritization of only one principle (economy). As noted above, strong sustainability promotes the preservation of nature equitably with economic development (Baker et al., 1997). In this sense, the interconnection among ecology, society, and economy are complementary and cannot be replaced. Daly and Farley (2004) indicate that ecology is the dimension that embraces economy and society by providing the needed resources for production and consumption. This does not mean that people who defend economic principles are wrong. They understand sustainability as supporting a healthy economic model that allows regions and

producers competing for markets, developing new products, and generating profit. A capitalist worldview considers innovation, competition, and profits as aspects necessary to survive in a neoliberal and globalized economy. However, those corporations, institutions, and individuals participating in the global economy should not remain indifferent to sustainability. They can integrate natural capital in economic and social systems through innovation processes and creative inspirations. Understanding sustainability can vary from region to region. For this reason, it is important that local spaces and communities which are integrated with governments, industries, universities, society, and natural ecosystems begin to define what sustainability means and its applicability to local agricultural systems. They should also consider the importance of integrating the three sustainability principles and their impact on people, communities, and environment.

Local communities should be the places to learn by creating knowledge spaces and networks for social cohesion, particularly for farming systems. Local communities are geographic concentrations where different actors serve specific roles, such as providers, consumers, educators, and competitors. For example, local (sometimes non-local) actors, such as HEIs, Industry, government, etc are all part of community. Local spaces can be learning communities and knowledge networks for sustainability. People living in the same local space share the local culture, language, history, and the environment. They share similar problems and work together to find new solutions to improve their quality of life and sustainable models to survive; in this case, the quality of life of local farming communities in terms of enough and healthy food, beneficial and productive crops, self-consumption, and self-sufficiency. In this way, quality of life means meeting personal, environmental, and economic needs. Quality of life is improved through innovations that help satisfy basic needs and living conditions. The World Bank (2010a) says that the achievement of quality of life for people should be supported by economic development, leading to prosperity and human welfare. However, many small farmers in such local spaces are still struggle to survive and are leaving farming because it is not profitable, or it is not enough to survive. They do not pursue this activity to be rich, but to be self-sufficient and ensure a certain quantity of production for sale. In the case of intermediate farmers, they produce for larger and external markets; thus, they need to improve the quality of their



products. However, due to various internal and external factors these producers struggle to achieve sufficient profitability and healthy products. For example, Norberg-Hodge et al. (2002) describe how millions of farming families are forced to leave the land every year because they cannot compete with a global food system and produce a living wage. For this reason, building innovation capacity, enhancing local practices, and having a consolidated knowledge network that supports the achievement of sustainability in local farming communities could help overcome this crisis. The learning interactions with farmers and other stakeholders can trigger the creative process through the emergence of new ideas and practices for better agriculture and integrating sustainability in terms of ecological and economic benefits. Local farming communities can increase their knowledge of how environmental and social practices can result in better economic conditions. Thus, the participation and integration of local community members in learning interactions and the decision making process can enhance innovation activities for achieving economic and social sustainability, including the use of natural capital.

The rational use of natural resources and environmental elements to achieve an ecological balance is seen as ideal under sustainability assumption. Indeed, the reduction of agrochemicals and the increased use of organic fertilizers are examples of farmer actions intended to protect nature. However, agricultural activity will always cause some environmental degradation, as one farmer indicated. It is difficult to avoid agrochemicals and fertilizers when managing highly automated and productive crops, especially over large land holdings. Gliessman and Rosemeyer (2010) state that there is a new generation of technological practices in agriculture contributing to environmental awareness and conservation of natural resources. Yucatecan farming uses a combination of old and new techniques and as a result nature has been less damaged; some governmental stakeholders and traditional farmers, through the ecological management program in coastal and rural areas, have tried to preserve its wildlife and plant diversity. This situation, of course, does not suggest that one or the other approach (old or new techniques) would damage the natural environment. This study suggests that better integration of modern and traditional knowledge would be ideal. Torri and Laplante (2009) highlighted the importance of improving innovation capacity through the integration of local and modern knowledge to

ensure practices such as ethnomedicine or traditional medicine. However, the current agro-economic model supports biotechnology for agricultural production (Vanloqueren & Baret, 2009) leading to a weak sustainability point of view. For instance, large producers have to buy international certified seeds and comply with international quality standards.

Governments are promoting the use of this technology and have many programs to allocate genetically modified seeds. In Yucatán, environmentalists and farmers share a negative view of genetically modified production, but they have to accept the use of agrochemicals to combat pests. The question is whether agro production systems will be preserved and under what conditions. Without the preservation of biodiversity and healthy agro-systems, not only nature is in danger, but also human survival (A1). This is why a greater understanding of sustainability (holistically) and an action plan in agriculture regarding the use of natural capital at local levels are crucial.

Despite global interest in promoting sustainability, there is no consensus on its implementation in agriculture. There are also no universal and consensual indicators for sustainability in local agro ecosystems. Some people tend to support economic sustainability rather than having an integrated point of view (Daly & Farley 2004). Others see agro-ecology as part of sustainability, including organic agriculture, prevention of soil erosion, and biodiversity (Gliessman & Rosemeyer, 2010). In this sense, defining and enforcing sustainability goals in local farming communities would be an advantage. Sustainability in México focuses on the conservation and improvement of natural resources, rather than a comprehensive development program, where the three dimensions of sustainability are interrelated. Even with some policies directed at sustainability in México, the government has not been able to establish a national knowledge network. Mexican policies in the field of sustainability in agriculture have not been considered in the development of local communities, including new production processes that support social, ecological, and economic welfare. These policies have been temporary actions directed to solve symptoms or unsustainable situations, but no real and clearly established policies and actions are in place. In fact, municipal councils are not prepared or trained to deal with sustainability in their local farming communities. For illustration, the Mexican law of sustainable development does not consider new techniques such as agro-ecological practice

for economic and ecological improvement of farmers; such policies focus on supporting economic efficiency through the development of technological innovation and the purchase of external inputs. There are identified problems in sustainability policy, including the lack of well-defined public policy with specific and applied actions in agriculture over the long term, the lack of involvement of private companies and greater participation of civil society and small producers, the lack of a social and ecological programs that should be complementary to economic and market approaches for the development of farming communities, the lack of government interest in consolidating a national program on sustainability where different actors are involved, not just the isolated efforts of individual institutions. Despite this discouraging situation, the combination of scientific, technological, and traditional knowledge may yet result in sustainable farming systems, and manage natural and human resources to foster and support sustainability through creativity and innovation. Thus, the creation of local innovation systems, where multiple ways of thinking, being, and knowing at small scales may increase the capacity of learning, interacting, and innovating to consolidate sustainability goals in agriculture.

## **5.2 Innovation for Sustainability**

Some issues mentioned in sustainability seem to overlap with the concept of innovation for sustainability, while other aspects seem to harmonize. The point is that innovation for sustainability is the result of the creation of new ideas, methods, or products through learning interactions and considering the principles of sustainability. I define innovation for sustainability as the production and application of new knowledge for social, economic, and ecological improvement of local communities. If innovation is successfully achieved, there should be a shift in work and action. New ideas or generated knowledge may or may not be commercialized. The generation of new or improved knowledge does not always have to involve an economic benefit, particularly when a range of local farming groups are engaged in building social alliances that help achieve sustainability. In the case of small and traditional farmers, their motivation to innovate is not for financial gain; they believe that knowledge should be created and shared through social interactions (Correa, 2001). Some innovations may start with a small idea; furthermore, they do not need to be disruptive or

radical, particularly in local farming systems. The integration of different disciplines and knowledge can improve existing conditions or practices. Thus, innovation should support and contribute to sustainability in farming through the generation of ideas and in turn the economy and social goals should be better integrated into sustainability. In this way, a definition, policy, and diverse alternatives of how innovation can contribute to sustainability should be elaborated; an emphasis on economic capital cannot be isolated from the social and natural capital. For instance, new or better practices and methods in agriculture such as polyculture and intercropping would preserve biodiversity and more sustainable agro-ecosystem, as well as the reduction of agrochemicals would result in healthy products with a positive impact on producers and consumers. This does not mean that all old practices, methods, or technologies should be changed. Indeed, technological knowledge has been applied to generate innovation over time and across sectors. Many developed countries have generated advanced technology, usually for commercial purposes, as part of their competitive advantage at the global scale. High skills, training, and the production of continuous knowledge are important components for the development of technology (Hague et al., 2011). Regional development depends on how knowledge is created and transferred for economic and sustainability goals. For instance, biotechnology innovation in Yucatán began twenty years ago with the habanero chile and other agro-economic products. Collaborative work between the academic and production sector started with targeting access to modern technologies and developing diverse and global markets (CONCYTEY, 2009). As I mentioned in chapter four, the production network for the development of the Yucatán agribusiness leverages resources through a synergy that included the farmers association, public institutions, and private organizations. With the creation of research, innovation, and technological development systems in Yucatán, technology, new crop varieties, and a germplasm bank were created as part of technological innovation for supporting agricultural production and commercial capacity. In this sense, biotechnology shows the relevance of scientific knowledge to our modern economy. Applied technology innovation has also shown an accomplishment through the creation of manuals and data sheets for the management and proper control of native seeds, as well as experiential learning and training for farmers. Nevertheless, traditional knowledge regarding genetic resources has been the basis for the development of

technological innovation without the recognition or disclosure of such knowledge in the process of copyright (Gómez & del Villar, 2009). Mayan farmers have been the pioneers in the management of seeds for years applying their personal experience and knowledge, but now, they and other small farmers have begun to adopt different types of knowledge and technology, particularly basic and applied science. In this way, agricultural innovation remains as technology and scientific knowledge transfer; there is little participation of producer groups in the research and data control. As a result it is researchers and other stakeholders must work together with farmers to develop new ideas and appropriate agricultural technologies. If different methods, techniques, and knowledge come together (innovation), better agricultural practices can lead to economic, social, and ecological sustainability.

Technological innovation has also been directed at solving environmental problems and supporting the use of ecosystem goods and services including irrigation systems, soil fertility, and appropriate technology. For example, more than 60% of producers in the Yucatán Peninsula apply both synthetic and organic fertilizers; the use of plants, trees, and agrochemicals to control pests, irrigate at critical periods, and practice weed control as part of their technology (CONCYTEY, 2009). Technological innovation contributes to ecological progress by developing and implementing appropriate/friendly technologies such as wind generators, composting, and manual techniques (Dorf, 2001). Technology and innovation in local farming communities should be seen as small improvements without the need to invest a lot of money. For instance, low and moderate technology is being developed in the Yucatán farming landscape and probably in many other farming communities of developing countries. In many cases, small and rural farmers have developed and adapted their own technology because they do not have access to certified or improved seeds, and have modest technical information regarding management of a sustainable production system. As a result, many small farmers preserve their traditions and culture, and most of them integrate local and traditional knowledge into farming management. For this reason and other factors, low external input agriculture is used by most Yucatecan smallholders including manure and composting, intercropping, and holistic pest management. These technologies foster the use of local resources that support small

scale agriculture with a focus on environmental improvement and self-sufficiency (Tripp, 2008). Indeed, the farming systems of most small farmers are oriented to self-sufficiency and the reduction of agrochemicals and fertilizers. Only intermediate farmers and agribusinesses have the resources to access improved seeds or participate in testable plots, through research control group, due to their financial capacity and openness to collaborate for better farming results, either sustainable or not. As Schumacher (1973) mentions in his book: “simple equipment and low and intermediate technology would fit much better in unsophisticated environment and be far less dependent on raw materials, p.149.” Also, it is important to highlight that the soil type of Yucatán does not allow producers intensive production, resulting in more environmental awareness. Nevertheless, as most farmers use a low technology, or their own knowledge and experience, a positive or negative impact can occur on ecosystems. Thus, new approaches on how technology can support environmental issues need to be discussed and trained at local spaces.

Perhaps an alternative for sustainability in local communities is fostering more agro-ecology and rural innovation. For instance, some farming communities have started to use agro-ecology as part of their farming system and some of them are still using traditional techniques (Snapp & Pound, 2008). However, the possibility of increasing production for export will not be met through agro-ecology and small scale production due to many local farmers not having higher production capacity for a foreign market, and there are not regulatory current structures and policies oriented to this type of farming. Engagement with the farming community, investment opportunities, and sharing know-how (the combination of the scientific, agro-ecological, and traditional knowledge) are necessary elements for creating new enterprises to achieve better ecological, social, and economic outcomes. In this way, a shift in local engagement and networking will make the local production system stronger and more sustainable. Furthermore new policies may help generate higher production at regional and local levels. In fact, most researchers are working with traditional and local farmers towards the improvement of soil and natural resource management; in turn, some local farmers are transferring their knowledge to scientists regarding how they managed their crops. However, all farming stakeholders would have to cope with challenges regarding how to increase production through more sustainable

techniques. This situation implies the recognition of local culture, language, and respect among diverse players. Breaking down socio-cultural barriers including education and income level, skills, and trust should be addressed. As a result, critical issues in agricultural innovation and sustainability that produce social, economic, and ecological benefits would be required. Current public policies and programs do not encourage diverse farming techniques and active participation and involvement of small farmers and civil society in the processes of innovation and production for sustainability. Better explanations and policies in support of innovation toward sustainability across sectors and levels are also needed. Thus, sustainability-based innovation will not be easy to achieve without the will of policy makers, key players, and civil society; but also, without the education and financial capacity, and the reconnection of key players who will search for alternatives.

New technologies should also support production for high quality and healthy products; as well technology in agriculture should ensure the continuity of farming for many years by protecting the environment and local farmers. The improvement of processes or products and the marketable capacity of new ideas or products are part of innovation that could lead to sustainability. Improvements to the production process should cover quality standards and production capacity, as well as producing healthy products. For sustainability, the production processes must meet quality standards while minimizing environmental impact. In order to cover quality standards and minimize ecological impact, producers have to understand national and international regulations, and how they can improve and develop better farming processes. However, increased and improved production, a larger economy, and economic growth do not necessarily lead to improved living standards or environmental preservation. Indeed, our modern economy prioritizes concepts such as cost-benefit analysis, minimizing the cost of production, using either renewable or non-renewable natural resource, and increasing output (Schumacher, 1973). For this reason, quality of production should consider better personal and technical skills, the rational use of natural resources, high standard of inputs (tested), and efficiency of technology. For illustration, only intermediate farmers are familiar with environmental standards and international quality of production requirements. They alone have the skills and resources to increase and improve their production through these mechanisms. Small farmers are not

involved. In this way, technology, innovation, and social cohesion among local producers are variables that can transform production techniques and local economic development. Through the revitalization of new kinds of alliances and farmers' involvement, local farming economies can be enhanced. As a result of this transformation the institutions and government need policies oriented to research, development, social learning, and sustainability. The production process is considered essential to economic growth and development, where the production, distribution, and consumption of goods and services are important elements for the economy, society, and ecology (Schumacher, 1973). New or improved technology and knowledge may or may not have a commercial purpose. If there is a commercial purpose, a need or motivation should be identified in the market as part of the commercial solution. However, both production and marketing should ensure biodiversity conservation, pest management, and community and economic benefits. Meeting quality standards, consolidating product systems, and participating in networks and associations will allow local farmers to produce in sustainable ways. Embracing cultural diversity, knowledge, education, shared values, trust, and collaboration represents a good opportunity for production and marketing. In this sense, the initiative to form cooperatives or social action groups in agricultural communities, associated with other institutions and regional companies would create a synergy for the creation of healthy products and their commercialization, with a focus on collaboration and social and sustainable learning. Local spaces can build their own wealth through the creation of local food movements and grassroots initiatives that may innovate in favor of sustainable forms of agriculture, production, and marketing (Norberg-Hodge et al., 2002). The improvement of production and marketing can be achieved by combining top-down and bottom-up strengths. The participation of local bottom-up players may increase production quality, healthy products, and sales capacity. Yet, this approach may be a challenge because of different internal and external barriers, including policies, financial resources, willingness, and the grade of local players association.

The ethical and social order of production oriented to solving needs and problems is another way innovation can contribute to sustainability. The awareness of innovation for sustainability relates to the creation of new ideas and innovative actions and activities for



solving related problems. There are two ways of identifying ethical and social problems as part of innovation contributing to sustainability; those related to producers and those related to the market. For instance, producers should be inserted in farming research and development as a social consideration, but also to get a more complete view of the regional production system. All producers should participate in the identification of needs and problems, and in the decision making process when a new project or initiative will take place. There should be more active and dynamic participation in agricultural research and innovation. Farmers, along with researchers and other stakeholders, are responsible for building know-how and know-what in their own local farming communities. This implies enhanced levels of association, triple loop learning, and a combination of diverse knowledge mechanisms. Ethical responsibility should also take into consideration when a new product or service is being introduced to the market. This new product must cover not only how it was processed and what kind of input was used, but also the minimal return on investment for producers. As a result, local farmers and research centers would participate fairly in the commercialization of products by obtaining an economic gain for the benefit of farming communities and research centers. This situation means that producers, along with researchers, need to consider new, better, and improved practices and methods to produce healthy products. Furthermore, consumers need to understand that they are paying a fair price for healthy products and are aware of our environment. For instance, more than 50% of small farmers in Yucatán may offer healthy products without the use of chemicals, to local communities, but they do not reach the capacity for external markets (Fundación Produce, 2011). For this reason, grassroots initiatives would be ideal for the promotion of ethical and social order in local farming economies leading to institutional and structural transformation.

Scientists, professionals, producers, and civil society have a social and ethical responsibility when innovating and producing knowledge and technology for the protection and promotion of safety and welfare of their local agricultural communities and society. Ethical education and practice should also be considered by HEIs. The development of new materials and methods should consider the rational use of natural resources, especially those resources that are non-renewable. Researchers and students should be involved in the

development of technologies that are friendly to the environment and better adapted to preserve agro-ecosystems. HEIs should link with local farming communities, especially to build and strengthen local farming systems (economically, socially, and ecologically). The ethical and social contribution of innovation to sustainability inside public and private institutions has to address how technological and non-technological innovation is generated, considering the needs of producers and markets, ecological concerns, the level of stakeholders' involvement, and the benefits for all local players and final consumers.

Not all innovation is associated with the development of technology. Processes, policies, and strategies are also considered part of innovation. Innovations change existing and outdated structures, obsolete public programs, or develop policies for new programs and mechanisms emphasizing the creation and application of new knowledge, strategies, and/or actions. For example, new social and farming programs may be generated that include small and rural farmers. Such farmers may be invited to receive information and training and express their opinion regarding what actions or activities would be important to implement to improve their agricultural prosperity and sustainability. However, many have not been invited or consulted; decision making is taking place at the top without consideration for sustainability in agricultural practice. In this region there are few social or institutional groups working towards social or ecological improvements in local farming communities. However, some stakeholders have started to meet informally to search for possible solutions to their problems. For example, intermediate producers meet informally to discuss issues related to the improvement of their farming practices, access to public programs and funding, and about their participation with researchers. Yet, they are not integrated formally with other local players for social and institutional innovation. Another concern is that cooperatives have dwindled, possibly because not many people are interested in working together in a communal farming system. In this sense, farmers and other social groups have not created a collaborative group towards the solution of common ecological and social problems in the local farming community, including training on the proper management of natural genetic resources and considering the economic and educational aspects of many rural farmers. In fact, it is difficult in Yucatán to create such agricultural groups due to the excessive political paternalism that has shaped the region.

One such paternalistic action is to give monetary and input support to small farmers; in this way, the government has control of farming activities. This situation has prevented some small farmers from innovating and learning from others to improve their farming practices (economically and ecologically), because some of them prefer to be dependent on government support and not take new ideas from others. For instance, Chile Habanero de Yucatán A.C. to which most small farmers belong, is associated with an office that collects and analyzes the best innovation alternatives around the world for small producers, such as the use of vermiculture to fertilize the soil, which is an idea that comes from United States. This does not mean that taking ideas from others is wrong; perhaps it represents a global opportunity to share different kind of innovations, especially when the adaptation and results are suitable for sustainability. But, it is better to encourage ideas and knowledge from the local farming community through the combination and expansion of know-how. This partnership for the generation of ideas would enable the identification of the needs and problems of the farming community, and the unity of all local stakeholders towards the development of legislation for the protection of collective knowledge (scientific, local, and traditional). Furthermore, social and institutional innovations are as important as technological innovations because they allow the integration and engagement of civil society with sustainable approaches (Snapp & Pound, 2008; L.H. Ketilson, personal communication, May 15, 2014). Social innovation embraces civil participation and strengthens local innovation systems to solve common problems (ecological and economic) and create new knowledge. The main problem is that farmers and other social groups are disaggregated due to cultural, know-how, production capacity, and policy factors. Farmers are not covered by a law or policy that protects their knowledge; there is no legislation that protects group innovation (farmers, researchers, and consultants), or a policy that supports the externalization and combination of knowledge. Overcoming these problems might promote the generation of new ideas and actions in favor of agriculture and sustainability. Then, local learning communities (cooperatives or informal groups) could promote social cohesion, new policies and actions, and innovative opportunities through the identification of similar values and social needs. The formation of social groups for combining knowledge and ideas (new programs and strategies) is a good alternative for advancing

sustainability, especially in those local and rural communities where many individuals maintain communal cohesion.

Innovation should not only contribute to sustainability by addressing social, economic, or environmental needs individually, but considering them as a whole to address problems and needs. A new process, method, policy, or technology, either for a production process or a public program generated by executives, farmers, or institutions, is part of innovation contributing to sustainability. The goal would be to share this new contribution with diverse players at different scales inside a local agricultural system, especially if the outcomes support sustainability. Phills et al. (2008) point out that social and technological innovation emerges as a disturbance to an institution or community, which leads to change and transformation. Innovation for sustainability is a response to a need or problem through the adaptation and transformation over time, which implies the way people do, transform, and use the natural resources of their places. Farming local communities acting as local innovation systems should usually involve diverse elements, including key social players, rules, policies, knowledge, beliefs, and financial support that should be interconnected to respond to sustainability. Despite how innovation can contribute to sustainability, the fact is that knowledge, beliefs, actions of individuals and institutions, and their interrelations with ecology and economy are part of sustainability-based innovation.

### **5.3 Opportunities and Challenges in Building Local Innovation Systems Towards Sustainability**

The presence of a local innovation system in this region began with the modest involvement of government, university, and industry. The focus on increasing habanero chile productivity, improving agricultural practices, and developing socio-economic impact studies is a clear example of the reorientation of government policies for innovation. However, there is still much to be done to establish an agricultural innovation system in the region that also considers sustainability. For instance, a Mexican research policy on sustainable rural development articulates that multidisciplinary teams should exist in working together for the improvement of rural communities, but this policy is not being implemented and evaluated by a coordinating academic body. Few researchers are collaborating and participating in multidisciplinary teams. There are no clear and applicable

guidelines for research and development regarding sustainability in Yucatán and México. In general, not many countries consider sustainability indicators as part of their system of innovation. In fact, little work has explored how local innovation systems work in the agricultural sector and what steps are necessary for a transition to sustainability. Even in many industrialized countries, linear and non-linear models of innovation do not consider sustainability principles. In these innovation models funding for research and development in academia focuses on single researchers or groups working on single projects/topics. This means that structural mechanisms for better interaction among researchers from different disciplines and between and with industrial, producers, and civil society are necessary. All efforts remain isolated without the convergence and unification towards the creation of innovation systems for sustainability.

A local system of innovation with attention to sustainability may be defined as a non-linear and dynamic system, where heterogeneous knowledge among multi-players is integrated and farmers and others are able to break away and create new paradigms towards sustainability in any sector. A local innovation system does not need to be a high-tech development. According to the results of this study, stakeholders define a local innovation system for sustainability as an interactive and dynamic web that includes the main actors in the production system (producers, HEIs, research centre, rural associations, industry, NGO, etc.) who leverage local capacities, improve farming processes, and add value to the system through knowledge and innovation for social, ecological, and economic well-being.

Therefore, this system can occur at small scales and in a specific sector and location for the improvement of processes, products, strategies, and technologies. Based on a systemic technological innovation framework, triple helix model, and my results, which includes structural and functional elements of innovation systems, I infer how knowledge may be generated and transferred. According to structural elements such as players, institutions, and interactions that are involved in a product system, I propose the consideration of the sustainability function as part of innovation system.

It is important to denote two sources of knowledge in the study region: 1) the critical mass and intellectual capital that is devoted to agricultural and biotechnology research and 2)

traditional practices and knowledge that the general public and farmers generate and transfer to other people in their communities as part of the innovation processes. The creation and dissemination of innovations among producers is usually informal and based on trust. Hoffman et al. (2007) say that formal and informal interaction can help externalize and combine knowledge among players for the solution of agricultural problems. It is good to generate new technology oriented to modifying production in ways that supports the development of new products to face current social and ecological issues of sustainability. New processes and more efficient alternatives would have less impact on ecological goods and services, including genetic farming material that resists pests. Yet, effective irrigation systems that reduce water use, less mechanized farms, and better locally adapted varieties of plants that supply healthy food are seen as methods contributing to ecological and economic sustainability. However, it is not clear how the creation and application of knowledge and innovation can contribute to sustainability from a system perspective. This situation is likely due to the inability to transfer and absorb knowledge in a system, including social and political rules, as well as informal and formal agreements to transmit information (Fabricius et al., 2005). Externalizing knowledge from one level to another has not been easy among stakeholders, especially for small farmers. Sometimes, farmers want to keep old beliefs and practices or do not have the ability to learn and absorb new knowledge. For executives and researchers, the socialization and externalization of knowledge is complicated because the level of education and language of small farmers is different. The codification of know-how and know-what is not easily absorbed by people with different levels of knowledge or skill. For this reason, some institutions have realized the vital role of liaison persons or key local players who bring together scientists and small and traditional farmers. These persons can communicate because they share the same culture, traditions, and language with both sides. Through well-designed mechanisms, local farming communities can improve participation and generate understanding between scientists, traditional people, and civil society. In addition, appropriate technology would be better for small farmers because such innovations do not require higher skills and inputs. In fact, they may not use advanced technology due to soil type or a lack of financial resources. In this sense, knowledge enrichment and appropriate technology may generate more economic and ecological benefits for agricultural stakeholders of the region.

Generating and transferring knowledge as part of the structural scheme of innovation system is essential. Studying the actors, institutions, and interactions will provide a better perspective on how to create innovation systems at the local level, which can functionally achieve sustainability through learning interactions and knowledge generation. The first thing to look at is the players, who they are, what role they should play within the system, and what their capabilities are. Key stakeholders are present in the region, but not all of them are present in the innovation systems. It is very common to see universities, public research centers, and government involved in research, innovation, and development. In fact, in México, these activities fall mainly in HEIs and research centers. They are the ones who generate and transfer knowledge through research, projects, human resources training, continuing education, which directly impacts the development of the regions. HEIs use different modes of knowledge (socialization, externalization, and combination) because they are the bridge among various local and regional players. As a sub-system HEIs have greater capacity to contribute to sustainability because they can include and apply the concept to practice, not only in the classroom, but also in labs, research, and the bonds they have with society in general. However, the term sustainability is not well understood and applied among administrators, researchers, and professors of such entities. This is mainly due to guidelines and policies at the institutional level do not consider sustainability a priority or an immediate action, only as a vision or something desirable. However, some isolated actions have begun to emerge focused on better practices in agriculture. Industry in this region has limited resources for doing research; however, new partnerships with HEIs have allowed the local community more opportunities to participate in technological innovation programs and access to public funds, strengthening scientific knowledge and the opportunity to patent a product for marketing. HEIs, industry, and government are part of a new dynamic environment with a commitment to contribute to the economy through research and development; but this dynamic does not include the involvement of all local stakeholders. Agro industries along with HEIs have generated knowledge and technology that benefit agro industries by offering their product or service to a specific market. Although agro industries have started to have more awareness and care for the environment, they do not see sustainability as something that can be fully integrated in their

production and social processes. As well, they do not include traditional and local knowledge as a valid input, mainly because of their interest in developing modern technology and delivering new products for the market.

Intermediate producers have also begun to realize the benefits of government programs to obtain technological advances for their plots and production systems. They often absorb knowledge, but such ideas rarely transfer to small farmers, unless they need higher production capacity to reach a particular market. As representatives of agribusiness, intermediate producers try to protect the environment and are aware of the economic and social benefits, but they have been unable to close the cultural and educational gap that separates them from other, larger producers. NGOs (Fundación Produce) have emerged as intermediaries in channeling resources, particularly in the transfer of technology to the agricultural sector through researchers who generate agricultural knowledge. Indeed, they started linking researchers with producers to create sustainable and productive plots at different scales. For instance, NGOs are working with rural people to develop sustainable farms at small scale where they combine diverse vegetables and animals for better waste management and emission of gases. Small and rural farmers generate their own technology, but they also receive external technology from researchers and agricultural agents. Perhaps they practice more organic production at small-scale and manage the irrigation system well, but they also have to learn sustainable practices such as the management of soil quality and fertility. Some financial institutions have also appeared as a production supporter in the acquisition of innovative technology or equipment to maximize production, but not as generators of ideas, or projects oriented to sustainability.

The second aspect to consider is the institutions or system regulations, legislation, laws, customs, habits, norms, traditions, and behaviors. This is known as hard and soft system approaches. In research, innovation, and development, especially in technological development, some regulations and legislations exist; these include genetically modified products that are not accepted in Europe for their commercialization. As well, there are regulations to license or patent an innovation for which a person or industry receives a financial incentive once commercialized. In the case of agriculture in México and Yucatán,



this incentive is usually for agro industries and research centers through their liaison office that can commercialize products or services. Public HEIs can also offer services or products to generate income, but not precisely for a commercial purpose, due to their legislation; however, they can encourage students and people to patent ideas and inventions. Conversely, the knowledge that local and traditional farmers generate and apply is not adequately protected under existing intellectual property law due to its communal nature. Therefore, these farmers do not participate in the process of patenting and marketing their practices, allowing other farmers to take ownership of genetic resources and receive any eventual economic benefit. This situation occurs because of a lack of information regarding process and a lack of interest in developing new legislation on sustainable practices in farming innovation systems, including the engagement of bottom-up players and more inclusive patent legislation, and the preference for technological innovation as a way to colonize rural agriculture. For researchers, the expectation (regulations) include continuing to receiving funding for their research, publish academic articles or books, and participate in academic knowledge translations; although some agricultural researchers run their own agribusiness and interact with small producers informally, their focus is in the generation of modern knowledge. Intermediate producers usually go to research centers to get, or collaborate for a new technology and they sometimes adopt a foreign innovation, especially to reduce costs and meet international standards. As a consequence, innovation systems do not have a well-established law of patents and commercialization of products generated by a local knowledge network, where all players might act jointly and receive social and economic benefits. For example, if successful sustainable production is derived from the learning interaction between two small farmers, an intermediate farmer, and a researcher, this experience will often not be transferred, perhaps due to the relationship's informality or the lack of patent registration for the collective knowledge on which it is based. Also, there is either legislation that moderates innovation systems and its impact on the three dimensions of sustainability (social, economic, and ecological) or there is information and diffusion on what and how innovation systems should work in the regions. Each player acts in isolation and according to their beliefs, customs, and social norms, particularly for small and traditional farmers because they act and make decisions based on their experiences,

beliefs, intuition, or the voice of a social leader. In fact, they do not know exactly what regulations and laws exist regarding sustainability, environment, or innovation processes.

As I said before, the law for sustainable rural development provides guidelines that must be met concerning sustainable development in agricultural areas of the country, but these are not concrete actions on how to achieve it in practice, what actors should be responsible for carrying it out, how to implement it, how to measure the final result, or if there are penalties for failing to meet these guidelines. The same situation happens at the product system level (habanero chile), this is mainly a result of the absence of a coordinating entity that would ensure guidelines and objectives are met, if not, the system loses strength and direction until it disappears. Isolated actions do take place by some actors in the product system. Many of the problems encountered are: lack of will, the cultural gap, personal habits, political and personal interests, and lack of working in partnership. If these problems are overcome, local innovation systems may be built. In addition, the ISO 14000 certification has emerged nationwide as part of recommendations from foreign institutions, especially among HEIs, which includes criteria on environmental management, but does not consider sustainability as a whole or holistic process. However, this certification does not guarantee that the institutions will have a positive impact on the environment or sustainability, since the indicators are more quantitative than qualitative. For example, an institution may measure how many liters of water is consumed during the month, but how to measure the beliefs and behavior of the users about the sustainable use of water, and its impact on the economy and society. Thus, rules are not well known or clear among local players, as well as social norms, personal customs, and prejudices are very strong at this level of interaction.

The third aspect is how learning interactions are occurring among local players inside the production system. Learning is a way of gaining new knowledge through doing, using, and exploring. The continuous repetition of production activities and experiences can increase learning for innovation and sustainability; this learning will be stronger at the group level than at the individual level (Lundvall, 1996). However, HEIs and Research centers are fragmented; one group develops basic research, another generates applied research. They

are not well integrated, and their functions are not guided by an innovation-learning interaction policy or political strategy. As a result, efforts to have a research impact on local communities fade because it is not perfectly linked. In addition, their sustainability-based innovation vision is not well-defined. Sustainability supported by innovation makes the concept more difficult to address. For this reason, it is needed that local players inside innovation systems should not only define this concept linking learning and sustainability with innovation, but also what its application and operationalization will be. HEIs should also reconsider their role in the innovation systems that support sustainability by generating new knowledge and ideas based on a new paradigm. Greater diffusion of technological innovation should follow how this was created and based on achieving sustainability principles. HEIs should also be the vanguard of innovation combining scientific, traditional, and agro-ecological production. The goal would be maintaining ecosystems, producer culture, and self-sustaining communities. For illustration, small farmers can learn by doing, sharing, practicing, and adapting a new technology in their crops from researchers or external agents, even if they do not have higher technical training. The problem is that there is a lack of participatory learning; researchers and farmers do not collaborate to develop abilities and new knowledge through mutual understanding and support. However, the potential benefits of interacting for learning concerning sustainability and innovation are: a) group decision making, b) complementing and strengthening infrastructure and intellectual capital, c) creating multidisciplinary research groups and knowledge networks, d) deepening knowledge for the use of natural resources. These benefits show the basis for building local innovation systems through the sharing of knowledge and information. Nevertheless, this interaction could result in small farmers adopting techniques that are less sustainable such as genetic farming material. For this reason, the involvement of diverse farming players in sharing their know-how through social networks is vital to recognize and face sustainability challenges in agriculture.

Generally, partnerships are being created between two players that exchange knowledge or infrastructure, such as between agribusiness and a research center to develop knowledge that will help the former to reduce production costs, but not necessarily having a positive impact on the environment. In this sense, the importance of learning and sharing

information with others is essential in achieving sustainability goals. Such interaction makes individual and social groups stronger, allowing them to face more complex issues than they might be able to alone. Nevertheless, to achieve learning interactions require overcoming some barriers. The main barriers are lack of willingness, attitude, and economic resources. These barriers include diverse players' commitments, institutional policies, addressing unrealistic needs or problems, distrust and jealousy, individual assessments, disjointed programs and sectors, and lack of funding for agriculture. Milbrath (1989) states that learning for sustainability should have goals associated with overcoming legal, social, and financial barriers, as well as the sharing of information, thinking holistically, and learning values and experiences from others. To this regard, the integration of scientific and traditional knowledge would be a good opportunity to analyze diverse interpretations and facts associated with unsustainable actions. The sum of the wills and strengths of scientists, civil society, and traditional people may promote sustainability, especially because traditional knowledge has an accumulation of expertise regarding the management of natural resources. Ashford (1994) says that willingness, opportunity, and capacity are relevant factors for the generation of innovation. For this reason, it is necessary to consider the lack of cultural understanding, and dissimilar beliefs and practices when sharing information for the creation of synergy and better learning interactions. If all local players may understand and balance the benefits against barriers, they may realize that building lasting learning relationships would allow having locally sustainable communities, especially in agriculture.

One of the benefits of learning interactions is the emergence of knowledge networks and inter-/multi-disciplinary groups across sectors and levels. These benefits enhance the dynamic interaction of innovation for sustainability. The co-development and collaboration of research and projects among diverse players can contribute understanding and adapting products and outputs to the needs and problems of individuals and communities. For instance, joint technological networks were implemented to boost collaboration between public institutions, agricultural colleges, and the local chamber of agriculture. This joint technological network encourages innovation through social and economic interdisciplinary

groups (Chave et al., 2012). The multiple advantages of creating a learning synergy through networks and inter-/multi-disciplinary groups are:

- The identification and solution of sustainability problems and needs through the sharing of experiences, knowledge, and resources.
- The articulation of a common vision for greater social and economic impact.
- Building multidirectional knowledge among diverse players and sectors. This includes the integration of different ways of knowing and thinking, not only scientific and traditional knowledge, but also across multiple disciplines of science.
- The participation and enhancement of small farmers and civil society in innovation processes for sustainability.
- The opportunity of building learning communities for the achievement of economic and ecological well-being.

Collaborative and knowledge networks are interconnections and social interaction among different players (Argote & Miron-Spektor, 2011). These interconnections are used by individuals and social groups to share and transfer tacit and explicit knowledge. These can be formal and informal. In this local community, informal meetings among producers and experts are usually conducted, but there are also formal agreements between two or more public and private institutions that support learning and sharing of knowledge. For example, CICY has collaborative agreements with two agro industries and some intermediate producers to improve soil fertility and seed production. In this sense, both institutions are learning and sharing information through the socialization of knowledge; although this interaction does not mean that there is a participatory action research because knowledge moves in only one direction. Thus, the creation and integration of knowledge networks and interdisciplinary groups would help the regions and communities participate in more dynamic learning interactions with the possibility of addressing complex problems through innovating for sustainability.

There are many barriers to overcome, but there are also opportunities. One of the biggest opportunities for this local innovation system is to create a coordinating system with its own structure (of rules, regulations, and actors). This coordinating body would align all stakeholders across sectors and multiple levels towards the same vision and objective.

Local innovation systems would provide civil society the opportunity to express their ideas, beliefs, and needs. In this case the farmers, extension professional agents, and alumni are part of the innovation system. They can share experiences and create synergies with other players within the system by generating ideas and providing solutions to local problems and needs. This represents triple loop and social learning in the innovation system. Another opportunity is to create a food system in local communities involving not only members of the agricultural sector and government, but also members of society who would participate as providers and consumers at the same time. The providers and consumers may interact, generating and transferring tacit and explicit knowledge. This opportunity can form the basis to consolidate self-reliant and sustainable communities. Also, it serves to strengthen agribusinesses among those small businesses and families who are working or processing a product at a small scale. Most importantly, the shift of focus and perspective of all stakeholders, including the government (with better and appropriate policies and public programs) and society with more active participation and engagement regarding social, economic, and ecological welfare, namely sustainability.

#### **5.4 The Function of Sustainability in Agricultural Innovation Systems: An alternative**

This alternative represents an opportunity to create a local innovation system that fully integrates sustainability principles. It has been created for the agricultural sector at the local level, but it can be applied to different sectors. Some applications and considerations for achieving sustainability in terms of agricultural innovation are: (1) deciding whether the adoption of a technology or technological packages are amenable to local conditions, it is appropriate for farmers, and it considers the natural limits; (2) assessing risk and environmental impact of a biotech design, and evaluate current crop management and waste management in agriculture; (3) listening to the voice and opinion of each individual/stakeholder/farmer in the process of generating ideas and decision making; (4) building strong and lasting relationships between local producers, researchers, consumers, agribusiness, and government; and (5) expand knowledge on sustainable land management based on technological and non technological innovation. There could be many other alternatives, but the point is how these can be applied and for what purpose in terms of achieving the social, ecological, or economic benefits.

Sustainability as an action tool is related to the interrelationship of all elements of the system or structure. For example, if knowledge about sustainable agriculture is not being generated in an agricultural innovation system, stakeholder participation and interaction is likely not being well stimulated either. As a result, the structure or system is unlikely to have satisfactory performance (Wieczorek & Hekkert, 2012), which in this case is because local actors are not spreading and applying the principles of sustainability in their plots. Thus, the key is to modify the system in such a way that sustainable principles are understood and applied correctly. Operational guidelines and stimulation for new policies scaling up and crossing all levels in a structure are needed. In this sense, structural capacity includes the necessary elements of the innovation system (new rules, knowledge, and collaboration among others). They are the stimulators that provoke change in the system. If one of them is missing, the system will not work. Also, if barriers and problems are not overcome, the system will never be consolidated. Systemic measures are the instruments and mechanisms that support structural capacity. These measures are the dynamic processes that indicate the performance of the system. This implies the presence of innovation policies that introduce and support sustainability principles. The presence of trust and will, as well as the involvement of civil society and traditional people, must be considered as an important aspect of successful sustainability-oriented innovation. Sustainability outcomes should be the goal of technological and non-technological innovation. These sustainability outcomes are based on the categories of sustainability that were identified in the results. The expectation is that innovation can better contribute to sustainability principles inside the agricultural system. The analysis and improvement of sustainability as a functional pattern in agricultural innovation systems can help us understand how sustainability may be fully supported by innovation.

The outcome is that the principles of sustainability are closely linked and should be within the guidelines of the system, as well as include a specification of the principles and how their effectiveness is evaluated. Then, sustainability could be seen as an evolutionary process that is related to other innovation functions and elements within the system, as illustrated in figure 5-2. Some aspects that may include sustainability principles are:

- Economic: profitability of production systems without exceeds the environmental limits, fair product price, self-sufficiency for producers, and availability of financial resources.
- Social: quality of life in terms of appropriate technology for solving farming problems, consideration of the culture and beliefs of producers, strengthening relationships with other members of the community and other local stakeholders, the importance of family in agriculture, and strengthening networks of learning and training.
- Ecological: less use of nonrenewable resources, prevent soil erosion and nutrient depletion, preserve biodiversity, avoid contamination of aquifers and cenotes, reduction and elimination of pesticides and chemicals, and improve irrigation systems.

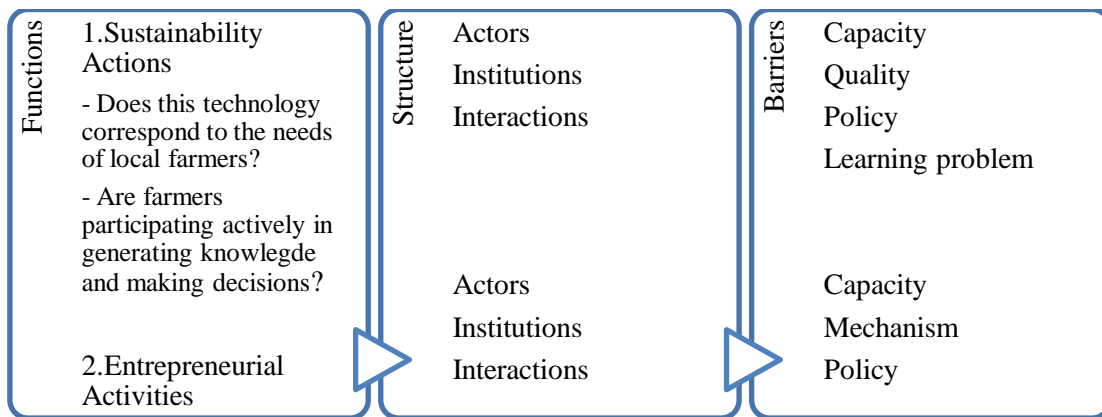


Figure 5-2.The function of sustainability in innovation systems.

Including diverse aspects of sustainability principles in systemic innovation processes results in a consolidated innovation framework, together with new policies and programs. Thus, sustainability principles and actions should be considered when a new innovation dynamics occur among local players. The proposal of including sustainability function in innovation systems should be taken into consideration by decision makers, local players, and civil society to re-connect the generation of new knowledge to the social, economic, and ecological benefits and needs of local communities.



### 5.4.1 Implications

The adaptation of policies from government and the presence of community governance in the proposed alternative is an important factor. This means that the creation of new regulations, education, and social cohesion play a crucial role in the emergence of sustainability principles. Although, there will be distrust and different attitudes, social cohesion and a common vision may help resolve these problems. For this reason, the importance of open forums for communication and participation, where civil society and traditional people can express their opinions and make recommendations for public policies and programs is essential. This is another implication, especially for policy makers at government and corporation levels, because they usually hold the majority of the decision making power, as the strongest actors of the system. This alternative is intended for local places, but building a new sustainability paradigm at regional and national scales is a possible opportunity. Disseminating opportunities may enhance learning and the adoption of new models that support sustainability through the lens of innovation. Institutional and public programs and mechanisms to create technological and non-technological innovations for sustainability can be developed through a depth analysis of this alternative. Policies and new legislations regarding intellectual property should also be addressed. Policy makers, scientists, technologists, businessman, and social entrepreneurs can find opportunities to understand their role as contributors to sustainability-oriented innovation. Finally, the implication of promoting adaptability and flexibility in innovation systems for sustainability in agriculture should remain a central part of the policy agenda at global and local levels.

The structure and functions of agricultural innovation systems for sustainability need to address new possibilities for policy and farming practice. In fact, actual policies do not include the following aspects:

- Establish public programs and policies to boost agro-ecological knowledge and other kind of knowledge and techniques, crossing sectors and levels. For instance, a synergy and alignment of policies and programs among government, public

institutions of agriculture, science and technology, and funding institutions will be ideal to strengthen the local innovation system towards sustainable practices;

- Create local knowledge networks for sustainability in agriculture. This action requires a common vision and framework where government and its institutions are responsible for the diffusion, significance, and training to all public officials and civil society;
- Individual research and knowledge networks should have a sustainability orientation for more and better integration and interaction between basic and applied research, as well as an enhanced application and transfer of knowledge to users. For this reason, the assessment of research productivity, patents, and intellectual property protection would have to change supporting appropriate mechanisms, networks, and multidisciplinary groups in the realm of sustainability;
- Create a multidisciplinary group (top-down and bottom-up players), to generate ideas or methods that support a more sustainable agriculture and work together towards the recognition and validation of collective knowledge for achieving economic and social benefits. As well, create a program within HEIs to join basic, applied, and traditional knowledge. This program might include experiential laboratories embedded in local and rural communities, where academic and civil society can generate intellectual wealth in favor of prosperity. Such an arrangement would deliver academic and economic resources to those communities, a change of attitude, and a change in policies and rules;
- The redesign of governmental programs, especially those focused on the provision of inputs and infrastructure to farmers in developing countries. As well, the function of monitoring and evaluating the results of such programs is needed;
- The promotion and implementation of a new legislation on intellectual property, which includes knowledge generated by social networks, and by local and traditional people who sometimes provide information for the development of technological innovation;
- Change the methodology for detecting needs, through consultation forums in municipalities (bottom-up approach);

- Create a system of communication and information to local communities about how to participate in projects. This means direct information and communication technology to local farming communities such as the internet for training and better engagement of people in public programs and notifications. However, many small producers do not know how to use a computer; it will be necessary for municipalities and public institutions to train them to realize the benefits of using this technology. Modes of communication and information dissemination need to be appropriate and developed and delivered to the recipients' level of education and cultural traditions, otherwise they would not be amenable to training and advice on this technology;
- Strengthen and continue with the public programs and political strategies that are working;
- Reorient the basic education system, especially in rural communities. Not only teach the core subjects, but also teach about and create sustainable small crops in communal gardens or at homes, and invite parents who wish to learn how to develop green gardens, better agricultural practices, and how to create the link with the government and other institutions to access funding, training, and support;
- Promote technological innovation and social entrepreneur programs in HEIs with an emphasis on local needs and unsustainable practices toward the achievement of social, economic, and ecological welfare. Policy makers can consider these recommendations to engage government and universities with other local stakeholders, where the flow of knowledge among them can address problems and solutions concerning the creation of an agricultural innovation framework that supports sustainability as an important function.

The last aspect is approached in more detail by examining how HEIs should contribute to sustainability. Two aspects should define the contribution of HEIs to sustainability: a) identify the impact of research projects that may revolutionize a production system and b) improve quality of life. As Cortese (2003) says “imagine future scientists, engineers, and business people designing technology and economic activities that sustain rather than degrade the natural environment and enhance human health and well-being” (p. 15). This

requires better engagement with communities and greater understanding of the current state, from different perspectives. The current way of innovating is changing, and so, more attention to significant transformations of production systems toward sustainable actions should be set. In fact, a current number of innovation projects and research are related to solving basic needs and problems including food production, water supply, and energy. Yet, this does not imply that innovation is contributing to sustainability per se. Dempere (2010) points out that the involvement of students in the selection of sustainable materials, and the incorporation of values and perspectives, specifically on quality of life and health issues, should represent a break for the introduction of sustainability practices to engineering students. A concept and vision for sustainability-based innovation should be established by HEIs through a) promoting participatory and multidisciplinary education and research in support of sustainability principles and, b) recommending public policies and mechanisms oriented to innovation-learning interaction for sustainability. Steiner and Posch (2006) show that multidisciplinary research and interaction between professors, researchers, and students with stakeholders of a region is crucial for sustainability because learning networks can be built. The integration of multi-stakeholders will result in improved well-being of local communities, fostering joint research (scientific and traditional), translating knowledge, and discovering different proposals for achieving sustainability.

If the trend is that in the near future there will be few jobs, more poverty, and reduced natural ecosystems, then individuals will need to be better prepared in an intellectual and business way with values, leadership, and grade of association, ethics, and respect. Stefik and Stefik (2006) suggest that new ways of thinking and resolving problems using different perspectives and disciplines supports the study of complex systems. For this reason, sustainability in HEIs not only lies in the design of eco-innovations, or programs oriented to protect the environment, but also the protection and inclusion of diverse cultures and knowledge. Inclusive and equitable HEIs are necessary, which are able to change ideas and attitudes, break paradigms and start to transform technological and non-technological innovations into something more human, friendly with the ecology, and prosperous for local communities. The role of HEIs is to encourage increased innovation skills of the

individual who can support sustainable principles, including creativity, critical thinking, problem solving and decision making, and social learning. However, critical issues must be approached by students and professors of HEIs, including working in farming, learning to be communal and sharing a common local vision, as well as living and experiencing the full agricultural production process in order to aspire to running an agricultural business. The idea is to provide individuals and students other types of experience and participation to see the reality, and the application and sharing of knowledge and innovation with other local and global individuals. In this way, theory and practice should be linked to better practice and technique putting an emphasis on agricultural practice, community involvement, and imagination. This contact with farmers and other local players will help HEIs to close the gap and generate knowledge for economic development and sustainability of local communities.

The collaboration and partnership between HEIs with industry and other productive sectors is essential to transferring knowledge. Joint research projects focused on solving sustainability issues would allow the development and transmission of knowledge among local players, including new skills and learning experiences within HEIs and from HEIs to local community players. In the region only a few industries, government, and some HEIs are shaping new forms of collaboration and sharing. However, there are some internal and external factors that impede this interaction. At the level of research HEIs and research centres, collaborative applied research is needed; such research must include farmers. This collaboration should be focused on research that targets actual problems or needs, for which different types of knowledge and resources will be shared and transferred, leveraging triple loop learning. The creation of social networks and alliances is usually the preferred mode of transferring knowledge. The transfer of technology allows HEIs to participate in the economy as technological centres or incubators. However, they are not generating and transferring knowledge for commercial purposes, they generate innovations that sometimes are transferred to industries or individuals for commercial purpose, and sometimes they are not. Thus, a strong liaison office for research and technological services is needed. The outreach of HEIs should include how to connect students and professors with alumni, producers, industries, and civil society. They should see reality and learn from different

perspectives to enrich their knowledge. This implies a transition from modern to experiential education. This means that the academic community should not only work in the laboratory at their universities by applying advanced technology, but also make practical and experiential field studies that include members of the local community. As well, collaboration with external research offices and other institutions to generate and transfer technological and non-technological innovation is important in terms of sharing infrastructure and financial resources. HEIs should also conduct non-research activities such as continuing education for civil society on sustainability principles.

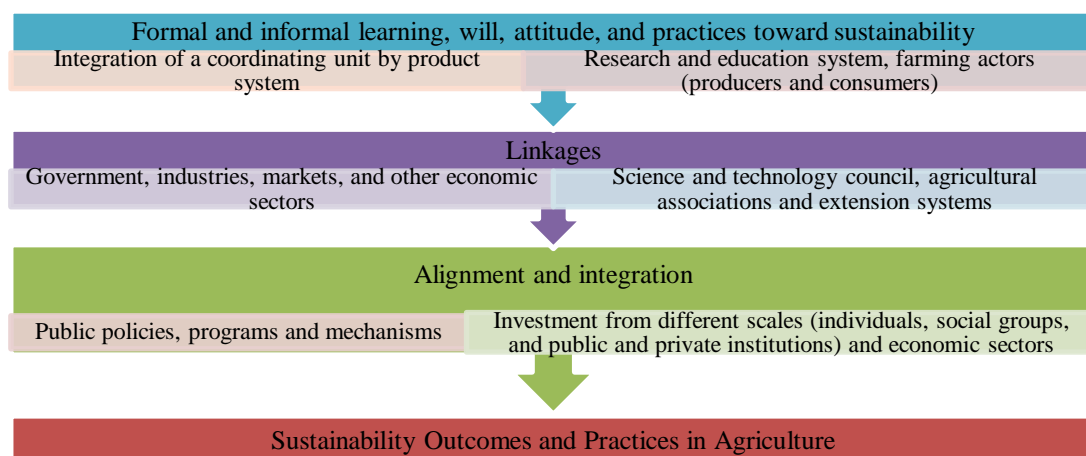
HEIs should not only engage in teaching, but also integrate businesses (industrial and agricultural) where students complete practical training in current and real situations. In fact, universities should strengthen the innovation and entrepreneurship program in the educational system and encourage students to be agricultural entrepreneurs. Trading and transferring knowledge for market might allow HEIs to earn revenues and students to receive funding; but this might also allow the inclusion of minority groups (small farmers) in such programs, as a means of empowerment and citizen participation to improve their living conditions. HEIs should be generators of technological and non-technological innovation for commercial, social, or ecological purpose. Thus, HEIs should support the integration of scientific and traditional knowledge into the definition and protection of the collective and social knowledge, through the agricultural entrepreneurs program, or knowledge networks. However, there are legal and financial issues in HEIs as enterprises, particularly in those Mexican public institutions that depend on federal government and public funding. Yet, they may advocate for legislation that allow HEIs to act as corporations in support of a local communities, including the inclusion and protection of collective knowledge, specifically traditional knowledge. In this sense, HEIs are training and research centres, but also represent an important advocate in the preservation of multiple ways of knowledge and resources, which do not necessarily have an economic benefit. Hence, researchers, professors, and students can bring a new or improved idea, or a new plan with the intention of improving the lives of society, the inclusion of civil society, restoring natural ecosystems, and preparing a path toward sustainability. This would mean the first step to build a path toward a social and ecological enterprise. Yunus (2010) defines

a social business as a “non-loss, non-dividend company, dedicated to achieving a social goal” (p.xvii). This means that an organization can earn profits or not, depending on its created mission. This kind of business is not formed to maximize profits, but is for a social cause and should be self-sustained. The creation of small-scale clusters of social entrepreneurs in local communities would also be beneficial. For instance, the integration of a social company inside HEIs can help identify an ecological problem, find the solution, and disseminate it with local communities and key players. In this sense, HEIs can respond to complex social and ecological problems, and alumni and all the academic community may discover new opportunities for solving wicked problems and the well-being of local communities. Overcoming researcher and key local players will and attitude can help to achieve this challenge. Public policies and legal mechanisms can also help to change this situation and support the transition of HEIs from the traditional model of teaching and research to build a social, ecological, and economic enterprise, as local catalyst of technological and non-technological innovation for sustainability.

### **5.5 The Perspective of Quintuple Helix in Local Spaces**

The presence of quintuple helix in this local system seems to be unfavorable or poorly developed. The conditions for learning and new relationships between top-down and bottom-up players are not present. Thus, government, university, industry, civil society, and grassroots initiatives to collaborate in knowledge production applied to natural environment and sustainability must be considered. The triple helix is emerging with certain knowledge infrastructure where some key players and institutions take place for innovation activities. The difference between these two approaches to innovation/knowledge production is the inclusion of civil society including producers and users inside agricultural innovation systems in support of sustainable actions. The issue is whether the government and policy makers may integrate a fourth (civil society) and fifth helix (environment and sustainability) within the innovation system. Additionally, the integration of diverse public and private institutions and their synergies are still emerging in local regions, but they are not yet consolidated. For instance, the strongest agribusiness in Yucatán region has formal agreements with public research institutions to improve and expand its production system,

but there is a disassociation with intermediate and small producers. According to some stakeholders this consolidation may happen in 6 - 10 years as new ways of thinking and learning emerge. Some open forums are starting to emerge for the engagement of civil society in public programs and projects. However, it is unclear if the voices of civil society are being listened to and considered by policy makers, or if they are even part of the decision making process. The concept of the quintuple helix is informative as it supports the contribution of innovation to sustainability, as it includes various actors across sectors and levels that are able to create new ideas and projects that benefit local and rural communities. If the integration of just two or three players is complicated, the integration of more players (like five in the quintuple model) in the scope of sustainability may be even more problematical. As well, every local farming player should align and commit to the interests of a product system, not personal or institutional interests. The government must lead with policies and programs that support the integration and consolidation of agricultural innovation system towards sustainability.



*Figure 5-3. Integration of a quintuple helix at a small scale (a cluster)*

The quintuple helix model may be a possibility if local players join strengths and leverage opportunities (knowledge, culture, experiences, practices, resources, and capacities) to build and consolidate a local agricultural innovation system for sustainability. They can join forces and develop linkages with other local and regional innovation systems to consolidate the national agricultural innovation system that farming communities need.

Figure 5-3 shows a possible integration of a quintuple helix at the small scale. This would



be similar to a cluster, which is a geographic and spatial concept where an interaction of tacit and explicit knowledge is created and disseminated by multiple local players for the increase of innovation capacity. In addition, the quintuple helix model does not explain how the environment and sustainability could be integrated into the innovation system, or what sustainability approach should be considered. Since a higher emphasis on natural environment is proposed, clarification is needed as to how sustainability as a whole sub-system would be approached. If there was empirical evidence of what the role of sustainability is in the systemic structural innovation would be useful. Also, it is not clear how regulations or social norms may work inside this model. This situation is due to those institutional and individual priorities, policies, personal and political interests, not only at local scale, but also at global scale, can block the emergence of this model. An important consideration is the history of every local space, and how social customs, acculturation, and power relations may also keep the civil society away to participate in learning interactions and the decision making processes. Every nation runs its own political agenda regarding innovation systems and sustainability. However, some advantages that governments and regions have for building this type of innovation model oriented to achieving sustainability goals are: a) research centres have a lot of experience in different knowledge disciplines, focusing on specific problems of the region, including the preservation of biological and cultural diversity and aquifers, b) the dynamic interaction of bottom-up and top-down players, and as a result, increasing know-how and community networking, c) new professionals interested in addressing sustainability principles and problem-solving processes, d) informal networks at different scales and spaces that allow the generation of knowledge and learning, e) governmental and political interests for more sustainable communities and prosperity that lead to openness, change, and transformation. These advantages represent a basis on which government and HEIs can create policies to contribute to and implement this innovative model. The introduction of a quintuple helix model can close the gap among key local players and promote learning interactions, know-how, and innovation for environment, society, and economy of local communities. As a result, a new opportunity to contribute to achieving sustainability may be given by creating this innovation model in diverse regions.

## CHAPTER SIX CONCLUSIONS

This thesis has highlighted the contribution of innovation for sustainability in agriculture. Learning interactions and local innovation systems play an important role in the generation of innovation for sustainability. HEIs are the logical innovative partner/locus that can contribute to sustainability through new ideas and supporting the improvement of local communities. I pursued the study of sustainability through the lens of innovation by analyzing multiple stakeholders and perspectives (top-down and bottom-up), and by considering the connection of innovation to reaching sustainability principles. The intention was to note the positive value of innovation for sustainability.

Studying sustainability through the lens of innovation new ways of interacting, knowing, and thinking for local farming players involved in habanero chile production. Both sustainability and innovation have been addressed and defined for the agricultural sector. This research analyzed how innovation might contribute to achieving social, environmental, and economic objectives as they pertain to sustainability. In this sense, sustainability encompasses not only a target, but three goals that are intertwined and complementary to one other, meaning that if one of them is overlooked, sustainability goals will not be reached. For this to be possible (the pursuit of all three pillars of sustainability), various factors and elements needed to be addressed. A systems approach was the most appropriate way to study these concepts as they pertain to one another and agriculture because they involve many elements belonging to a bigger system. Rules, human actions, beliefs, and values are all part of such systems; learning and adaptation are also important characteristics of the proposed system. This study confirmed how difficult it can be to define and relate sustainability and innovation. In general, the results showed that sustainability is synonymous with quality of life, financial security, environmental preservation, and welfare for all, crossing the three principles of sustainability (social, economic, and ecological). Innovation for sustainability is the generation of new knowledge and ideas for the solution of social, economic, and ecological challenges. However, the conditions for achieving sustainability goals may not be held equally across regions and local communities. Many different barriers can inhibit innovation and how it

might contribute to sustainability. For this reason, it was relevant to study the contribution of innovation to sustainability from an innovation systems approach, as both concepts can evolve, transform, and adapt over time.

Innovation systems include science and technology, which support progress and development. For many years, science and technology were the engines of rapid and competitive economic growth and synonymous with innovation. This rapid technological advancement was pursued with relative disregard for the social and environmental damage caused. In fact, people are still generating technology that harms the environment, and by extension society. As science and technology imply knowledge generation and innovation, redirecting them towards a better quality of life, in all social, economic, and environmental aspects seems important. Associated with this case study, biotechnology has contributed to agricultural development through improved seeds. However, not all producers have benefited from this improvement as they cannot access this resource and continue to work with their own tools and technologies. Therefore, innovation and knowledge should help address the real sustainability problems of local producers and communities. Technological innovation can contribute to sustainability through the development of solutions to ecological problems and support social and economic progress. Technological innovation does not necessarily mean more or advanced technology, especially in local and rural communities in developing countries. Most of the time, people from these communities have neither the economic capacity nor the training for such adaptation. Appropriate technologies, which they can adapt and implement, would be ideal. Less intensive production through the use of low technology can help to establish farming continuity, and thus achieve sustainability, where not only the social and ecological justice is considered, but also economic justice. This means that the contribution of technological innovation should consider improving living standards as well as sustainability principles. However, as I have suggested technological innovation is not the only path to sustainability; non-technological innovation through grassroots initiatives at local spaces can also support sustainability actions in agriculture.

Non-technological innovation can also contribute to sustainability. There is an opportunity for local communities to shape social groups and knowledge networks for the solution of social and ecological problems through innovation. The engagement and participation of local stakeholders allow the integration of better social programs and innovation incentives for sustainability. In this sense, policies and mechanisms of innovation should be addressed by public and private institutions to better contribute to sustainability principles. Social groups and grassroots initiatives can enhance innovation activities, moving towards sustainability. On the one hand, they can help improve living and environmental conditions, enhancing the skills, education, learning, and collaboration of residents and individuals. On the other hand the creation of new strategies and ideas for better practices on farming, maximizing production and minimizing environmental impact and natural resources. Thus, new visions and alternatives regarding the relationship between sustainability and innovation should be examined by groups at local levels. In fact, innovation and sustainability depend on the adaptation and learning of people inside the system: how people create, innovate, and share, and how they build their production capacity and coexist with nature. Learning for innovation and sustainability is important, as the repetition of practices and joint activities allows stakeholders to build and disseminate new knowledge. If the participation of bottom-up stakeholders increases, there will be a better use of learning toward economic and ecological security for local communities, because they are part of such innovation system. Non-technological innovation includes new programs and actions, where diverse players with different stages of knowledge inside a system participate, for a more dynamic learning interaction toward sustainability, particularly in agriculture. Thus, the protection and recognition of all stakeholder knowledge should be assured by new legislation.

A local agricultural innovation system is a recent concept that is not well understood among local governments and players. In this research, the product system (habanero chile) illustrated that through a non-linear engagement of different stakeholders, the creation of new knowledge and paradigms, and learning interactions at a small scale a contribution to sustainability can be made. The benefits of small scale production are consistent with how local players interact, learn, adapt, and change in the face of new economic and ecological

conditions. In fact, in my study area, local stakeholders have started to create and share innovation and knowledge through formal and informal mechanisms of knowledge generation, training, and education. However, this case study identified barriers and opportunities that local innovation systems and sustainability in agriculture have to address; these include the emerging interaction among multiple players at different scales, the poor participation of smaller farmers (smaller land holding and production), and the lack of a common vision of innovation for sustainability. Thus, consolidating this system through better structures and functions capacities, including learning and education, intellectual property, policies, programs, new rules is needed, as is the will and trust of people toward sustainability outcomes. Some of the challenges include the inclusion of different types of knowledge to solve sustainability problems and the integration of civil society and bottom-up stakeholders in the design and decision making of new strategies, policies, and ideas that support sustainability. An alternative proposed in this study is the creation of a sustainability function inside agricultural innovation systems. This alternative reflects how innovation can relate and contribute better to sustainability, starting with the clear definition and strategies of how to create this approach at this scale. The perspective of local innovation systems for sustainability can help policy makers, researchers, producers, businessman, and civil society to look into the future, rethink and redirect policy goals, build capacities, and implement and measure the transition of enhanced social, economic, and ecological outcomes.

One new perspective introduced here is the quintuple helix model that has the intention to include the natural environment and sustainability as a sub-system of a larger innovation system. It is a co-existence between humans and nature, where the interaction and exchange of knowledge is essential to make changes and innovations that impact the environment directly. This implies triple loop learning through the formation of social groups and knowledge networks. These networks oriented to the system in question can enhance learning and understanding of how innovative ideas may solve ecological and economic problems. This model relies on the interrelation of universities, government, industries, and civil society with a focus on the environment. This model considers HEI sub-systems as an important axis for the generation and diffusion of knowledge and research. In this sense,

HEIs will have to reassess their role in the innovation systems that support sustainability by generating and transferring new knowledge and ideas. All of which should be based on the preservation of nature, find new ways to develop technology, do business, accept different points of view and knowledge, and invite and involve people with different values and reality to understand the place where people live and meet their needs. This reassessment means profound functional and ideological changes, including attitudes, ethics, and a deep understanding of how the generation and transfer of technology can contribute to sustainability. HEIs need to close the gap and bring together citizens, researchers, policy makers, and multiple players for sharing diverse skills and experiences in the realm of ecological, social, and economic benefits for all. If HEIs contribute to market competition through the development of higher technology and intellectual capital, they will also need to contribute to social justice and the engagement of minority groups in decision making processes, which can impact, positively or negatively, local communities. This is a challenge for current models of innovation, knowledge generation, production processes, and knowledge transfer. HEIs as innovators and economic developers have a responsibility to create advances for adapting and transforming technological innovation in pursuit of sustainability. HEIs are part of knowledge networks and can appear with the goal of building clusters or local innovation systems devoted to developing more sustainable practices, knowledge, and products that are friendly with nature. HEIs must consider how to best create new local spaces where bottom-up players can be involved in innovation systems for sustainability and support the intellectual property of collective knowledge. In addition, the creation of social innovation and social enterprises inside HEIs may help to boost technological and non-technological development in favor of social and ecological issues. HEIs also have responsibility to renovate knowledge and attitudes across scales and sectors by understanding that innovation for sustainability is not about maximizing productivity over sustainable practices in the production processes. They can be catalysts of human resources that support the creation of technological and social innovation for long-term community health, in this case in support of sustainability in agricultural innovation systems. Thus, HEIs inside quintuple helix model can support the insertion of sustainability as a function in innovation systems.

In conclusion, the contribution of innovation to sustainability in agriculture relies on new ways of generating and sharing knowledge, new ways of thinking, innovating, and learning. New approaches and frameworks are needed to discuss and understand what policy and mechanism transformations are required to change current ways of innovating and create those that support sustainability. Support of innovation for sustainability should happen through the creation and implementation of new knowledge for the improvement of living standards, quality of life, economic stability, and the desire to protect the environment. Innovation for sustainability requires action and practice, but in doing so, local players and policy makers must be mobilized in a mutual will to participate and collaborate to build local innovation systems that support the social, economic, and ecological welfare of people and their communities. One problem might be the generation of innovation and learning interactions among different actors, but it could also be the incorrect understanding, application, and orientation of sustainability. First, many people do not understand this term or how sustainability can be applied in an innovation system. Second, other people believe that sustainability will not be possible to achieve, because the balance among its three dimensions usually leans toward the economic, leaving less acknowledged the environmental and social dimensions. However, changes and transformations are not automatic, but require gradual and subsequent shifts in know-how, perceptions, and actions. I believe innovation contributing to sustainability in farming is: a) the active and committed participation of citizens in a dynamic application through triple loop learning, b) the government interested in opening doors and hear different voices for the design of public policies and programs that help to improve the environmental, social and economic conditions of local farming communities, and c) creating partnerships and multidisciplinary knowledge groups between industries, HEIs, and producers, to create and strengthen a common sustainability vision in innovation systems through the association of different stakeholders and social cohesion. Thus, the contribution of innovation implies the sum of the desire, attitude, engagement, and opportunity in more informal and formal ways of learning for sustainability.

## **6.1 Limitations and Further Research**

This research is limited in some ways. The purpose of this study was to analyze the contribution of innovation to sustainability in agriculture practice. It explored the concept of sustainability and innovation, but it would be interesting to examine innovation systems that support sustainability in different locations and sectors. Application of the framework for non-agricultural sectors represents an opportunity to develop a critical contribution of innovation system toward a sustainability transformation. While, I believe the quintuple helix model is a good system for supporting sustainability, further research might be the empirical analysis and comparison of the triple helix model for sustainability. Moreover, innovation for sustainability was not studied from the perspective of sustainable agricultural outcomes, such as the quality of agricultural output, including type of inputs, chemicals, and risk assessment. Thus, defining an appropriate approach that includes such sustainability outcomes in agriculture might be addressed elsewhere. Additionally, it would be interesting to explore how sensitive innovation for sustainability is in the face of more advanced knowledge networks and clusters such as Silicon Valley. Since this study looked at innovation related to sustainability, finding knowledge networks and learning interactions at this scale would be interesting and relevant. Rural innovation and sustainability would be an attractive research area and could explore opportunities and challenges that rural societies face regarding complex social, economic, ecological, and legal problems (intellectual property); particularly the recognition of traditional knowledge in the research processes of developing countries. Finally, some aspects of social innovation and social enterprise have been mentioned, but were not analyzed in depth. Future research might explore the political and cultural dimensions of HEIs, serving as social and ecologically responsible companies through the innovations generated by research labs and students for the solution of local community problems and needs. This can also include an approach to how to register collective knowledge legally promoted by HEIs along with other local players.



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## APPENDICES

### Appendix A: HEI Consent Form (English)



**Behavioural Research Ethics Board**  
**HEI CONSENT FORM**  
**TECHNOLOGY INNOVATION FOR SUSTAINABILITY**

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**Purpose:** The purpose of the research is to analyze learning interactions and local innovation systems for the generation and transfer of innovative agricultural technology, by examining the impact and contribution of higher education research to agriculture and sustainability. I would like to invite you to participate in my study. So I need to ask you some questions to examine collaborative processes and local innovation systems for the development of agricultural technology innovation that impacts on social, economic, and ecological aspects of farming communities. Your permission to use this current information in my research is needed. Your insights will provide to understanding the benefits of learning processes for the generation and transfer of agricultural technology innovation related to sustainability, and the identification of barriers to build local innovation systems.

Please read this form carefully, and feel free to ask questions you might have.

**Procedures:** The data for this study will include a report analysis of your institution from 2009 to 2012, a list of researchers and alumni working on technology innovation for agriculture (habanero chile), and the liaison chief who will be interviewed. As well, other key players will be interviewed including governmental authorities, industrial executives, and local farmers. The oral interviews which will take place in person at a location of participants choose during 90 minutes. Focus group will be conducted only with alumni and farmers during 100 minutes. Data from the interview and focus group will be recorded, and hand-written notes when are needed. The results of the study will be disseminated through graduate student theses, academic publications, and conference presentations.

**Potential benefits** of the research include understanding the impact of higher education research and education on the improvement and welfare of local farming communities. An effort to build a new conceptual approach to understanding sustainability vision of innovation in higher education institutions will be made, by analyzing collaborative processes and knowledge networks in generating, and transferring innovative agricultural technology. A review of the existing social learning literature will be included. As well, this research will contribute to understanding on how technology innovation may support

rural communities achieve a social and economic welfare, as well as give practical alternatives to ecological problems.

**Confidentiality:** The information gathered will be kept confidential and your identity concealed. One risk to confidentiality and/or anonymity is that given the small community of participants, you may be able to be identified by someone in your personal or professional community. This possible risk is reduced by reporting data via a general synthesis, replacing names with pseudonyms, and deleting potentially identifying information.

**Storage of Data:** The original data will be stored as a password protected electronic file. Only Dr. Scott Bell and I will have access to the original data. The information will be kept in locked offices for a period of at least six years.

**Right to Withdraw:** Your participation is entirely voluntary and you can choose to decline to answer any question or stop participating at any time. As a participant you have the right to withdraw from the study. If you choose to withdraw, any identifiable record of the information given during the interview will be destroyed and deleted until data has been pooled. After this it is possible that some form of research dissemination will have already occurred and it may not be possible to withdraw your data. A choice to withdraw will not affect your relationship with the researchers, or with the University of Saskatchewan and their services.

**Questions:** If you have concerns or questions at any time concerning this study, please feel free to ask Dr. Scott Bell or Mayanin Sosa at any point. Any questions regarding your rights as a participant may be addressed to the Behavioural Research Ethics Facilitator at the University of Saskatchewan, 306-966-2975 or toll free at 888-966-2975.

**Follow-Up:** Copies of results and published articles will be allocated once the study is concluded. You may also be asked to authorize a transcript release form to include some selected quotations.

**Consent to Participate:**

I have read and understood the description provided; I have had an opportunity to ask questions and my questions have been answered. I consent to participate in the research, understanding that:

- I may withdraw my consent to participate at any time.
- My input will be audio-recorded.
- The information that I share during the dialogue will remain confidential unless I choose to be identified by presenting in a research conference.
- I will have an opportunity to review or make changes to direct quotations before inclusion in papers or public presentations.
- Data will be used for a PhD thesis, conference presentations and/or publications.
- A copy of this Consent Form has been given to me for my records.

I have read the information and I agree to participate in this study.

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Participant - Print Name	Signature	Date
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Lead Researcher - Print Name	Signature	Date
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**Researchers' Contact Information:**

Dr. Scott Bell Lead Researcher Tel. 306 966 56 76 email: <a href="mailto:scott.bell@usask.ca">scott.bell@usask.ca</a> Academic and Scientific Director The Spatial Initiative University of Saskatchewan	Mayanin Sosa Alcaraz Graduate Student Tel. 999 9446004 email: <a href="mailto:mas650@mail.usask.ca">mas650@mail.usask.ca</a> School of Environment and Sustainability University of Saskatchewan
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## Appendix B: HEI Consent Form (Spanish)



### Oficina de Comportamiento Ético de Investigación

#### FORMULARIO DE CONSENTIMIENTO PARA IES

#### INNOVACIÓN TECNOLÓGICA PARA LA SUSTENTABILIDAD

**Propósito:** El propósito de la investigación es analizar las interacciones de aprendizaje y los sistemas locales de innovación para la generación y transferencia de tecnología agrícola innovadora, examinando el impacto y la contribución de la investigación de la educación superior en la agricultura y la sostenibilidad. Me gustaría invitarle a participar en mi estudio. Así que tengo que hacerle algunas preguntas para examinar los procesos de colaboración y los sistemas locales de innovación para el desarrollo de la innovación tecnológica agropecuaria, lo cual impacta en los aspectos sociales, económicos y ecológicos de las comunidades agrícolas. Se necesita su permiso para utilizar esta información actualizada en mi investigación. Sus ideas proporcionarán a la comprensión de los beneficios de los procesos de aprendizaje para la generación y transferencia de la innovación tecnológica agropecuaria en relación con la sostenibilidad, y la identificación de las barreras para crear sistemas locales de innovación.

Por favor, lea esta forma cuidadosamente y no dude en hacer preguntas que usted pueda tener.

**Procedimientos:** Los datos de este estudio incluirán un análisis del informe de la institución desde 2009 a 2012, una lista de investigadores y alumnos que trabajan en la innovación tecnológica para Chile habanero, y el jefe de enlace que serán entrevistados. Además, otros actores claves serán entrevistados, incluyendo las autoridades gubernamentales, directivos de la industria, y los agricultores locales. Las entrevistas orales se llevarán a cabo en persona en un lugar a elegir durante 90 minutos. La discusión grupal se llevará a cabo con los alumnos y los agricultores durante 100 minutos. Los datos de la entrevista serán grabados, y notas escritas a mano cuando sea necesario. Los resultados del estudio serán difundidos a través de tesis de posgrado, publicaciones académicas y presentaciones en congresos.

**Los beneficios potenciales** de la investigación incluyen un análisis sobre el impacto que tiene la investigación de la educación superior en la mejora y el bienestar de las comunidades agrícolas locales. Se hará un esfuerzo para construir un nuevo enfoque conceptual para entender la visión de sostenibilidad de la innovación en las instituciones de educación superior, mediante el análisis de los procesos de colaboración y redes de conocimiento en la generación y transferencia de tecnología agrícola innovadora. Una revisión de la literatura de aprendizaje social existente se incluirá. Además, esta



investigación contribuirá a la comprensión de cómo la innovación tecnológica puede ayudar a las comunidades rurales a alcanzar un bienestar social y económico, así como dar alternativas prácticas a los problemas ecológicos.

**Confidencialidad:** La información obtenida será confidencial y su identidad será ocultada. Uno de los riesgos para la confidencialidad y / o el anonimato es que dada la pequeña comunidad de participantes, es posible que pueda ser identificado por alguien en su comunidad personal o profesional. Este posible riesgo se reduce en la presentación de datos a través de una síntesis general, sustituir los nombres con seudónimos y eliminar información potencial de identificación.

**El almacenamiento de los datos:** Los datos originales se almacenarán en un archivo protegido por contraseña electrónica. Sólo el Dr. Scott Bell y una servidora tendrán acceso a los datos originales. La información será protegida y se mantendrá en las oficinas por un período de al menos seis años.

**Derecho de Retiro:** Su participación es completamente voluntaria y usted puede optar por negarse a contestar cualquier pregunta o dejar de participar en cualquier momento. Si decide retirarse, cualquier registro de identificación de la información proporcionada durante la entrevista serán destruidos y eliminados hasta que los datos se han agrupado. Después de esto, es posible que alguna forma de difusión de la investigación haya ocurrido, y no puede ser posible retirar sus datos. La opción de retirarse no afectará su relación con los investigadores, o con la Universidad de Saskatchewan y sus servicios.

**Preguntas:** Si tiene dudas o preguntas en cualquier momento con respecto a este estudio, por favor no dude en preguntarle al Dr. Scott Bell o Mayanin Sosa en cualquier momento. Cualquier pregunta sobre sus derechos como participante, puede dirigirse a la Investigación del Comportamiento Facilitador de Ética en la Universidad de Saskatchewan, 306-966-2975.

**Seguimiento:** Copias de los resultados y los artículos publicados serán distribuidos una vez que el estudio haya concluido. También se le podría pedir autorizar una forma de liberación de transcripción para incluir algunas citas seleccionadas.

**Consentimiento para participar:**

He leído y entendido la descripción proporcionada, he tenido la oportunidad de hacer preguntas y mis preguntas han sido contestadas. Doy mi consentimiento para participar en la investigación, entendiendo que:

- Puedo retirar mi consentimiento en cualquier momento.
- Su información será grabada en audio.
- La información que compartiré durante el diálogo se mantendrá confidencial a menos que elija ser identificado mediante una conferencia de investigación.
- Voy a tener la oportunidad de revisar o realizar cambios en las citas directas antes de la inclusión en los documentos o presentaciones públicas.

- Los datos se utilizarán para una tesis doctoral, presentaciones en congresos y / o publicaciones.
- Una copia de este formulario de consentimiento me ha sido otorgado para mis archivos.

*He leído la información y acepto participar en este estudio*

Nombre del participante	Firma	Fecha
Dr. Scott Bell		
Nombre del investigador principal	Firma	Fecha

**Contacto con los investigadores:**

Dr. Scott Bell Investigador principal Tel. 306 966 56 76 email: <a href="mailto:scott.bell@usask.ca">scott.bell@usask.ca</a> Academic and Scientific Director The Spatial Initiative University of Saskatchewan	Mayanin Sosa Alcaraz Estudiante de Posgrado Tel. 999 9446004 email: <a href="mailto:mas650@mail.usask.ca">mas650@mail.usask.ca</a> School of Environment and Sustainability University of Saskatchewan
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## Appendix C: In-depth Interview Guide

Stakeholders: Policy-makers, HEI Liaison Chief, Industrial Executives, and Researchers.

Topic/Variables	Questions
Research, education and extension services policies, programmes, and mechanisms.	<ol style="list-style-type: none"> <li>1. What are those programmes and mechanisms to foster agricultural innovation or just innovation?</li> <li>2. What are some agricultural technology innovations you are creating or adapting?</li> <li>3. Do you think that these policies and programmes regarding innovation reflect the expected and current sustainability outcomes, notably related to the well-being of local communities? Explain please.</li> </ol>

Topic/Variables	Questions
Partnerships. Collaborative projects and research on agricultural innovation.  Social, economic, and ecological benefits.	<ol style="list-style-type: none"> <li>4. Do you collaborate with other actors through partnerships or agreements?</li> <li>5. How important to your innovation activities is collaborate with other actors?</li> <li>6. What joint projects or research are you working on habanero chile?</li> <li>7. Who are your main collaborators?</li> <li>8. What are some problems for learning and sharing knowledge with other local actors?</li> <li>9. What forms of communication do you use for sharing knowledge and learning with other stakeholders?</li> <li>10. What are some problems for the development and adoption of new agricultural technologies among diverse players (industry, farmers, and researchers)?</li> <li>11. Have you collaborated with local or Mayan farmers?</li> <li>12. How has your relationship been with them?</li> </ol>

	<p>13. What types of impact may agricultural technology innovation rely on local farming communities?</p> <p>14. What is the role that (HEIs, industry, government) should play in achieving sustainability innovation?</p> <p>15. What does sustainability mean to you?</p> <p>16. What does innovation for sustainability mean to you?</p> <p>17. What is the role of HEI and government should play in achieving sustainability vision of innovation?</p> <p>18. What are some barriers for building innovation systems that promote or contribute to sustainability?</p> <p>19. What is a local innovation system?</p> <p>20. What are some of the benefits of collaboration for the development and transfer of knowledge?</p> <p>21. What have been some important contributions of innovation generated or not by a HEI to farming communities?</p>
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## Appendix D: Focus Group Guide

Stakeholder: Farmers and Alumni

Topic/Variables	Questions
Adaptation of new technology or technique in agriculture. The consideration of social, economic, and ecological benefits.	<ol style="list-style-type: none"><li>1. What are some technological adaptations you are making or have made for the habanero chile?</li><li>2. Who developed, transferred, and adapted such technology?</li><li>3. What types of programmes or incentives are offered for the development of agricultural technology?</li><li>4. What are some social, economic, and ecological effects of a new or improved agricultural technology or knowledge?</li><li>5. What other agricultural techniques and traditional knowledge have you been using in your activity?</li><li>6. How does a HEI research participate in agricultural innovation? Can you give examples?</li><li>7. What does sustainability mean to you?</li><li>8. What does innovation for sustainability mean to you?</li></ol>

Topic/Variables	Questions
Collaborating with researchers/alumni/farmers. Partnerships and agreements.	<ol style="list-style-type: none"> <li>9. How important to you is collaborate with researchers, industries, or governmental authorities?</li> <li>10. What are some problems for the development and adoption of new agricultural technologies among diverse players (industry, government, and researchers)?</li> <li>11. What are some of the benefits of collaboration for the development and transfer of knowledge?</li> <li>12. What is the role of HEI and government should play in achieving sustainability vision of innovation?</li> <li>13. What are some barriers for building innovation systems that promote or contribute to sustainability?</li> <li>14. What is a local innovation system?</li> <li>15. Are there other ways by which you are collaborating and learning for the creation of agricultural innovation?</li> <li>16. Have you collaborated with Mayan farmers/Alumni/or local people on research and innovation activity?</li> <li>17. Are there agreements, contracts, informal or formal research networks, by which you are participating in agricultural technology development? Can you describe it?</li> </ol>

## **Appendix E: SWOT Analysis Guide**

### **(Strengths, Weaknesses, Opportunities, and Threats)**

Stakeholders: Industrial executives, alumni, HE liaison, governmental authority

Guide of Analysis:

1. Description of a local innovation system, and the identification of barriers or problems to build innovation systems towards sustainability.
2. Analyze the strengths, weaknesses, opportunities, and threats of collaborative processes and learning interactions for the creation of innovation on the local vegetable industry, and the contributions of innovation to agriculture and sustainability, including local players such as HEI.